Art with Socrates

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Part 1

Geometry

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Introduction

This book, *Art with Socrates* is an introduction to the classical order of art instruction that has its roots in antiquity. Drawing and painting seem to be an almost natural activity of the human person. The point is highlighted by the drawings and paintings in caves that date from the time period known as prehistory. These early human beings depicted animals, people, hands, etc. on the walls of caves. It is astonishing to reflect that human beings at that time felt the need to make images of the visual world on the walls of their homes.

Historically, Western art is considered to have began in Ancient Egypt with hieroglyphs and wall paintings. As the Greek world began its rise and developed into one of the most astonishing civilizations in human history artist expression also developed from a merely two dimensional representation of the world to three dimensional illusion of the world. Art would develop into what is called now called Classical art. The artistic representations of Ancient Greece are still considered to be a summit of artistic achievement.

Such an achievement in art was due to the importance that ancient Greek society gave to art in its various forms. The greatness and abundance of art in the ancient world attests to the importance it had in society. Art and beauty were not considered to be something of second rank. On the contrary, art was an intrinsic part of daily life for ancient peoples. The famous ancient philosophers Plato and Aristotle both reflected in different ways on what art is, the unique importance of art in the life of the city, and its proper role in the education of youth.

The importance given to art education and its role in society has changed over the centuries. Indeed in our time drawing and painting instruction are seen to be as something that is done for fun, and art is really just a spontaneous expression of feeling. However, this is an extremely new development in education that stems from certain recent art theories .

Walter Smith the former art director of public schools of Massachusetts in the late eighteen hundreds wrote in his book, *The American Textbook of Art Education,* “Art Education is a subject so broad in itself, of such great importance in all practical life, and so valuable educationally, that instruction in it should begin contemporaneously with education in language and number…Art Education even for little children, means something more than instruction in drawing. It comprehends the cultivation of the eye, that it may perceive form; of the hand, that it may represent form graphically (drawing); of the mind, that it may receive and express ideas in regard to form”. And, “it is desirable that in drawing the hand should obey the mind as readily as possible…”

The importance of art in education has not changed despite the lack of importance given to it in education. Many young people today love art and desire to learn to draw and paint beautifully. This thirst of young people was described in an outstanding way over 650 years ago. Cennino Cennini writing in the fourteenth century described the type of young person that was attracted to art. In his work “*The Book of Art*” he writes, “It is the stimulus of a noble mind which induces persons to study these arts, made pleasing to them by the love of nature. The intellect delights in invention; and it is nature alone, and the impulse of a great mind which attracts them without the guidance of a master…those who pursue them(*the arts*) from the love of art and true nobleness of mind are to be commended above all others."

What order should be followed in teaching art? This question is of the utmost importance because the starting point is that from which which everything else follows, and upon which everything else is built upon. It seems to us that the starting point of drawing should be what is the most simple and easiest to understand. Drawing, the basis of all visual art, consists in making marks on a two dimensional surface just as the cavemen did when they painted on their cave walls. The most simple and easiest way of understanding the different kinds of marks that can be made on a page, and what shapes these marks can formed by them is geometry.

It may seem somewhat odd to think of geometry as being the starting point for art education, but geometry is simply the study of three dimensional objects on a two dimensional plane. Indeed the literal meaning of the word geometry is measurement of the land. Sebastian LeClerc, a perspective instructor at the *Royal Academy of Painting and Sculpture* in France during the 17th century wrote in his book "*Practical geometry: or, a new and easy method of treating that art"* that the origins of geometry occurred in Egypt. He traces the birth of geometry to the very practical need that the Egyptians had to be able to measure their land accurately because of the annual swelling of the Nile River. The flood waters would cover the land and after the water had drained off the Egyptian needed a way to measure out what land belonged to them before the flood. Starting with this very practical need the Egyptians then developed the form of measuring land into the knowledge of geometry.

Geometry became the art and science of representing the real world that exists in three dimensions on a two dimensional surface. Geometry uses points and lines and combines them to make shapes. This making of shapes by using points and lines is drawing at the most basic level.

Drawing though is something that is analogical. There is not only one form or one way to draw. There are many different kinds of drawing. However, drawing always implies points, lines, and shapes. For examples architects use drawing to express the idea of a building, a painter uses drawing to express an idea or to locate where colors go on a canvas. A sculptor will use drawing to express the volumes of three dimensional figures, a cartoonist uses drawing to tell a story. Drawing is done in many different ways depending on the idea the artist wants to express. Even handwriting can be considered a certain form of drawing since it also uses points, lines, and shapes. We can express our ideas through drawing shapes or through writing,

This book takes a very practical approach to teaching art by starting with the simplest elements of geometry. These elements are described in words and illustrated on the following page by examples. After having read the text and seen the examples, students are encouraged to follow the step by step process of drawing the different elements as written in the following lesson.

Words are used in a precise manner so that students can learn to associate what they read and hear to what they see. The order taken in the lessons is based on the natural and different ways that we learn.

In following this order of study this pedagogical approach seeks to integrate different kinds of sensory knowledge so that what is sensed can be understood. For example, the teacher should be able to show the students examples of points, lines, circles, squares, etc. by drawing them on the board and using wooden examples of spheres, cones, est. so that the students can see and touch them. It will be easier for them to draw the things that they have experienced by touch and sight.

This book also approaches learning art by following Socrates approach of asking questions of about what we experience. Before tudents begin to draw there are a series of questions that will be asked that will help them to be attentive to their observations.

The following books on art will focus on drawing, values, and color. They will build upon what is taught here.

The exercises in this book are written for someone who is right handed. If someone is left handed it may be easier to follow the steps by doing the hand movements in the opposite direction.

There is also a YouTube channel called Art With Socrates that demonstrates the different lessons taught in this book.

*The materials needed to complete the exercises in this book are a #2 pencil, colored pencils, a straight edge, a compass, and regular copy paper.

The Elements

The *Elements* is a book that was written over two thousand years ago by a man from ancient Greece whose name was Euclid. Euclid is called of the father of geometry. In his book he wrote about points, lines, shapes, and how they are related to one another.

In this book about art we will learn about some of the things he wrote about in 300 b.c. For instance, we will learn about points, lines, and shapes. What are points, lines, and shapes? How can learning about geometry help us learn about art? Those are important questions. As we read this book we will learn the answers to those questions, and we will also discover how learning about geometry can help us to learn how to draw and paint. We won't be using any numbers as we learn about geometry. We will be learning how to see things and how to describe what things look like. After we have seen something, and described what it looks like, then we will begin to draw it. When we are able to see correctly drawing and painting will be easy.

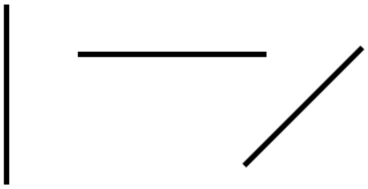
For example on the next page we can see some of the basic elements of geometry. We can see a point. We can see two kinds of lines. Straight lines look different than curved lines. We can also see different shapes. Each of the shapes has its own characteristics, that means each shape looks a certain way. If we ask how do the shapes look different from one another would we be able to explain their differences? We can also see how some shapes look as if they have three dimensions. How can we draw something that looks like it is round? What shapes do we start with to make something look like it is real?

Those are some of the questions that we will answer as we read this book and learn how to draw by following the exercises.

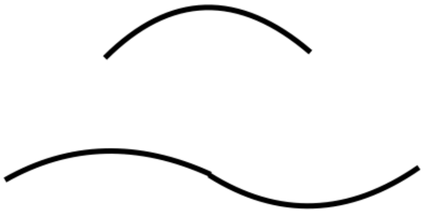
The Elements

Point

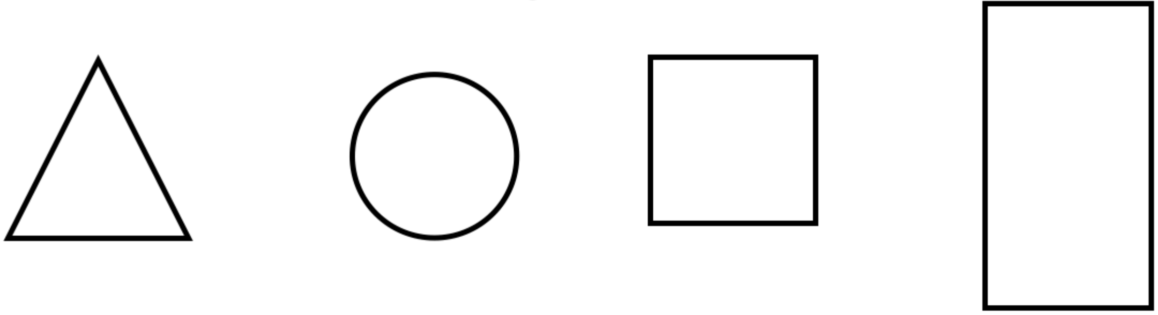
Straight Lines



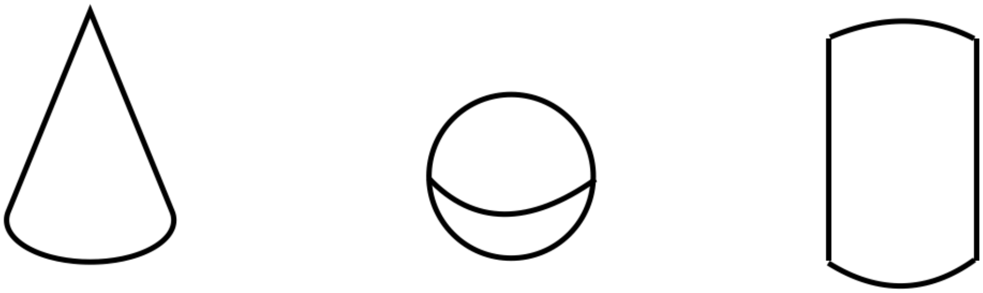
Curved Lines



Figures



Three Dimensional Figures



Point

The first element of geometry that we need to learn about is a *point*.

What does a *point* look like? On the next page we can see an example of a *point*.

What is a *point*? Why do we use *points*?

A *point* looks like dot or a period that we use at the end of a sentence. It is the simplest geometric element. A *point* is neither tall nor wide. It does not have any parts. A *point* can be made with a pencil, a pen, the point of a compass, or by putting a small hole in the paper.

A *point* is used to show where a line begins and where a line ends. A *point* shows where a line begins. This is called the *starting point* of line. A *point* also shows where a line ends. This is called the *end point* of a line. In the example on the next page we can see an example of the *starting point* of the line in green, and the *end point* of the line in red.

A *point* is also used to show where two or more lines meet or cross over one another. This is called an *intersecting point*.

A *point* is also used to show where the center of a shape is. This is called a *center point*.

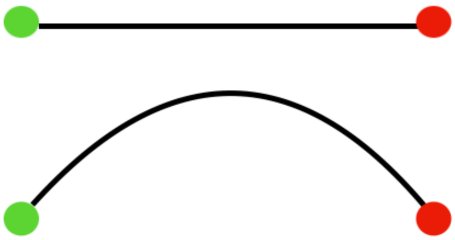
A *center point* is also used as the starting point from which a circle can be drawn.

In this first lesson we learned what a point is. How do we describe what a point looks like? How it is used? What is a point? Are points used only by themselves or can a point be at the beginning of something and at the end of something?

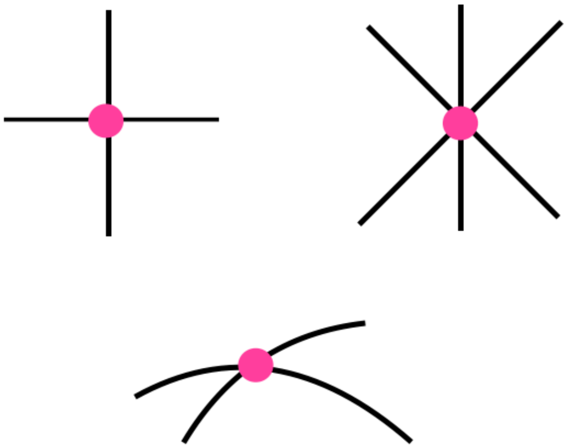
Point

Point

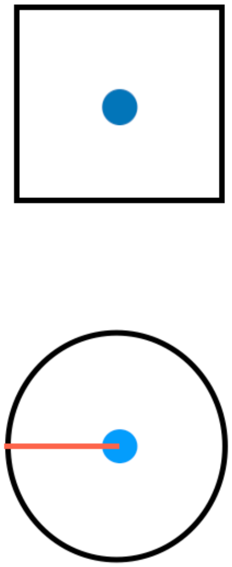
Start Point and End Point of a Line



Intersecting Point



Center Point



Lines

The second element of geometry that we need to learn about are *lines*. On the next page we can see different kinds of *lines*. What do the *lines* look like? How do the *lines* look different from one another? What is a *line*? Why do we use *lines*?

A *line* is a length, it describes a distance. A *line* shows how long or how short something is. A *line* also shows us different kinds of movements. A *line* shows us the way things move. A *line* can show us that something goes up or down, side to side, or if it curves.

A *line* has beginning and an end. A *line* starts with a *point* and ends with a *point*. The starting point and then end point of a *line* are its extremities.

The first kind *line* is called a *straight line*. A *straight line* is a *line* that moves in only one direction. It is also the shortest distance between two points.

The second kind of *line* is called a *curved line*. A *curved line* is a *line* that moves in more than one direction. It curves in different directions.

How do *straight lines* and *curved lines* look different? What kind of movements do they show?

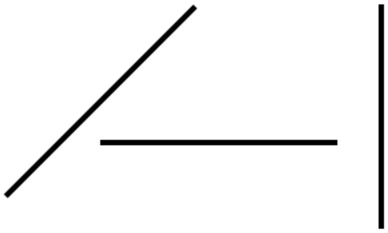
The third type of *line* is called a *reversed curved line* or an s-curve line. A *reversed curved line* is a line that has two curves that move in opposite directions. It looks like the letter s.

The fourth kind of *line* is called a *mixed line* because it is formed by using a *straight line* and a *curved line*. It has a straight movement and curved movement between its starting point and end point.

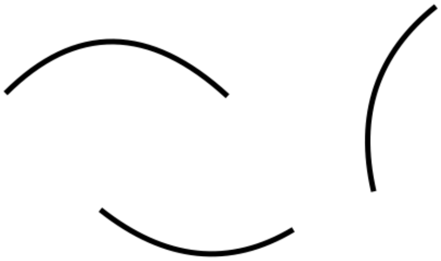
The fifth kind of *line* is called an *implied line* or a *hidden line*. It is called a *hidden* or *implied line* because it suggests or indicates where a line may go.

Lines

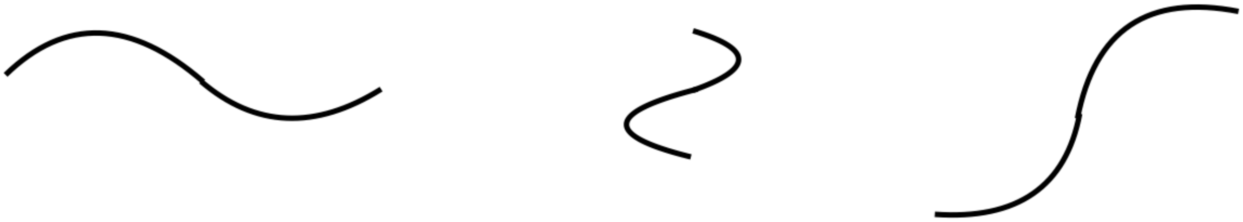
Straight Line



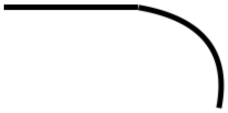
Curved Line



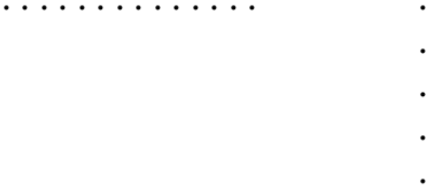
Reversed Curved Line



Mixed Line



Hidden Line/Implied Line



Straight Lines

The first kind of lines we will learn about are *straight lines*. On the next page we can see examples of three different kinds of straight lines. How do they look different from one another? What words can we use to describe what makes each *line* unique? What kind of movements do the different *straight lines* show?

The three kinds of *straight lines* are called *vertical lines*, *horizontal lines,* and *oblique lines.* We can see that they are all *straight lines*. A *vertical line* shows us an up and down movement A *horizontal line* shows us a side to side movement. The side to side movement can also be called a left to right movement. An *oblique line* shows us a tilted movement.

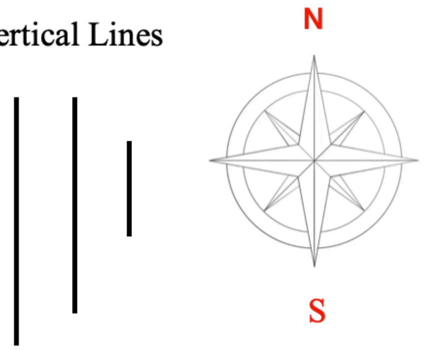
The first straight line we will learn about is the *vertical line*. On the next page we can see examples of three vertical lines. What do they look like? What kind of movement does a *vertical line* show? What is a *vertical line*? A *vertical line* is a line that shows a movement that goes straight up and straight down. We can see that it does not lean to the left or to the right at all. On a compass it would point directly north and south.

The second straight line we will learn about is the *horizontal line*. On the next page we can see examples of three *horizontal lines*. What do they look like? How does a *horizontal line* look different than a vertical line? What kind of movement does a horizontal line show? What is a *horizontal line*? A *horizontal line* is a line that shows a straight side to side movement. A *horizontal line* moves from the left to the right or from the right to the left. A *horizontal line* does not lean up or down at all. On a compass it would point east and west

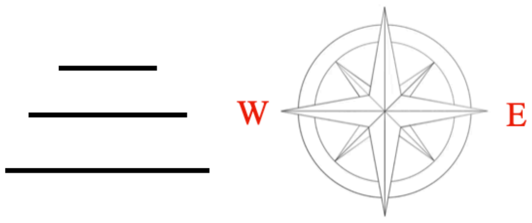
The third straight line we will learn about is called an *oblique line*. On the next page we can see examples of four *oblique lines*. What do they look like? What kind of movements do *oblique lines* show? How do *oblique lines* look different than *vertical lines* and *horizontal lines*? What is an *oblique line*? *Oblique lines* look different than vertical and horizontal lines because they don't move straight up or down, or side to side. *Oblique lines* are tilted. They show an angular movement. Any straight line that is not a *vertical line* or a *horizontal line* is an *oblique line*. On a compass an oblique line would point any direction except north, south, east, or west.

Straight Lines

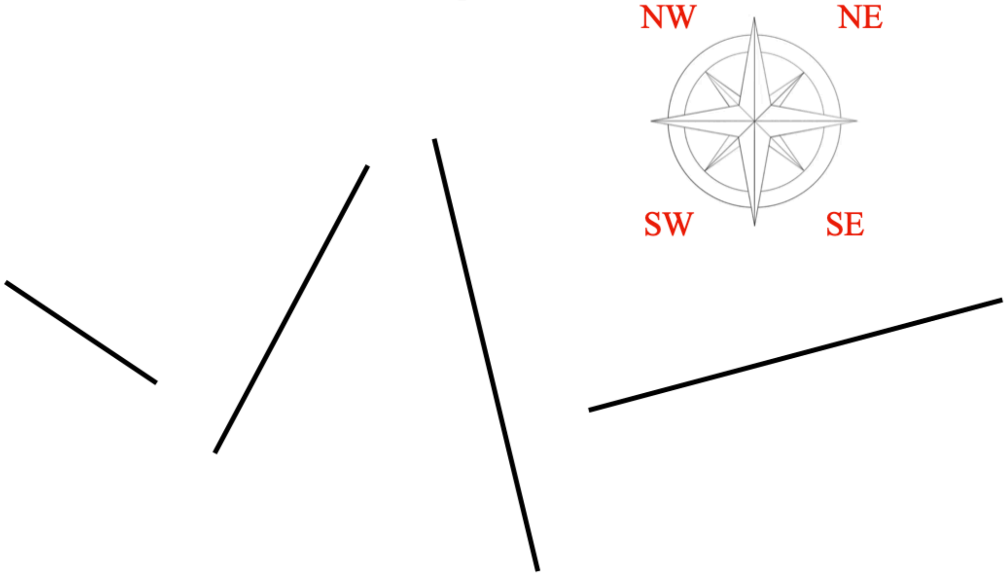
Vertical Lines



Horizontal Lines



Oblique Lines



Introduction to Drawing and Drawing Vertical Lines

We will now begin to learn to draw. In the beginning, as we learn to draw we will always place points before we draw any lines. We will place a starting point and an end point. As we get better at drawing we won't need the points anymore. The points will show where the line will start and where it will end. It will also show us how long a line will be and what movement it will make.

It is ok if the lines are not perfectly straight. The goal is to learn to see and to learn to draw. Before drawing a line we *first* need to look at the starting point and then end point. Once we have seen how long the line will be and what its movement is then we can begin to draw. When we draw we need to keep our eyes looking just in front of of the pencil point. We do this because our eyes will show us where to draw the line. Our hand always follows our eyes.

Now we will learn how to draw *vertical lines*. What do *vertical lines* look like? What kind of movement do they make? What is a *vertical line*? Earlier we learned that vertical lines move *up* and *down*. The words *up* and *down* are in red because those words help us to understand what movement the *vertical line* makes.

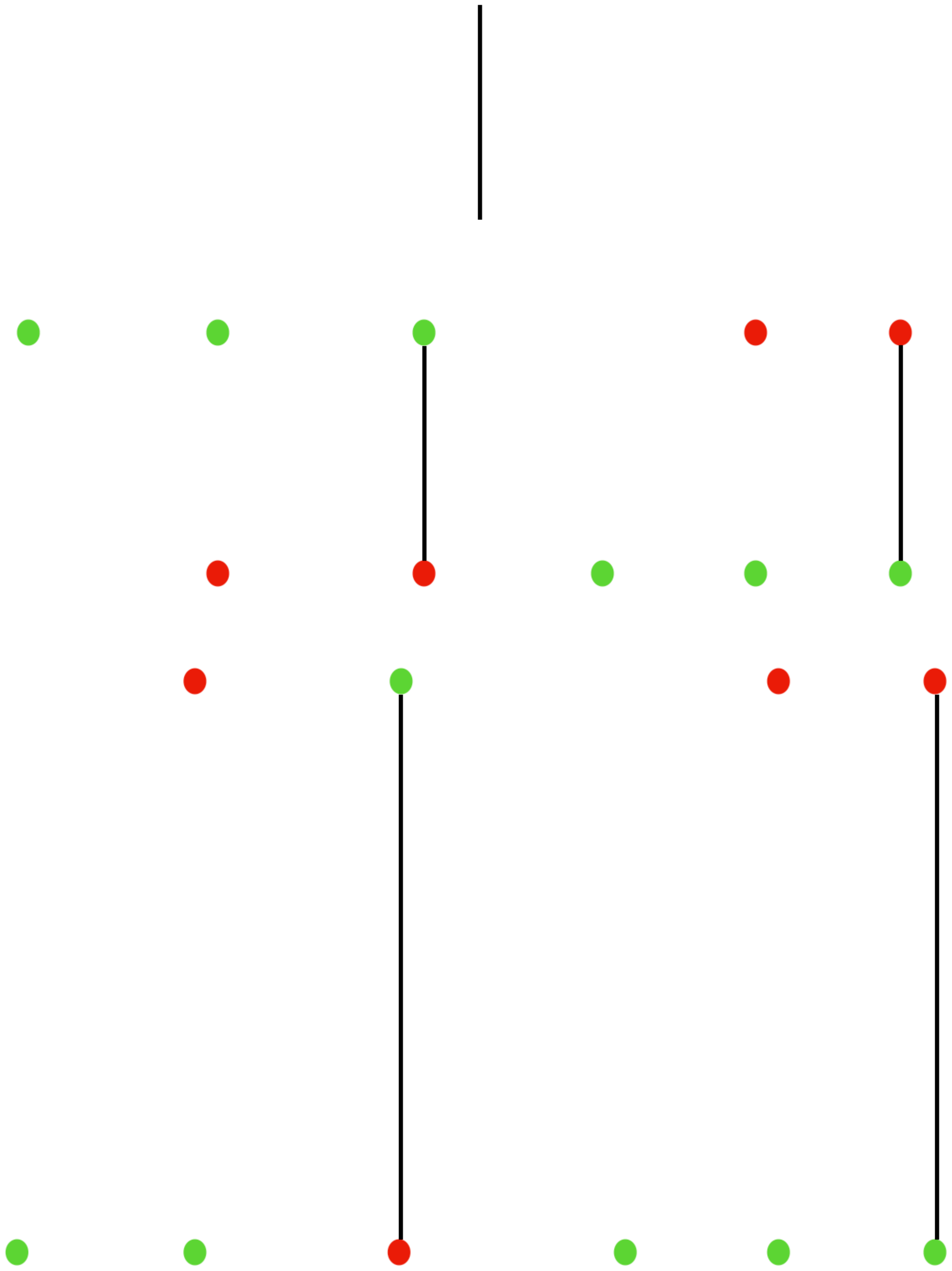
The word *vertical* comes from the Latin word *verticalis* which mean vertex, or directly overhead.

To draw a *vertical line* the first step is to place a green point on a piece of paper as we see on the next page. This shows us where the *vertical line* begins. Then *under* this point we need to place a red point. This shows us where the *vertical line* will end. Now beginning at the green point we need to draw a *vertical line* that moves *downward* and stops at the end point. This *vertical line* runs *downward* because the end point is *below* the starting point.

Now we will draw a *vertical line* that moves *upward*. To do this we need to place a green point lower on the page. Then *above* this green point we will place a red point. Now beginning at the green point we need to draw a *vertical line* that moves *upward* and stops at the end point. We can say that this *vertical line* runs *upward* because its end point is *above* its starting point.

Now we will make two more *vertical lines*. These two *vertical lines* need to be longer than the first two lines that we drew. We need to follow the same steps that we used when drawing the first two *vertical lines*. One of the lines should run *downwards* and the other should run *upwards*. Both of these lines should be longer than the first two lines we drew.

Vertical Lines



Drawing Horizontal Lines

Now we will learn how to draw *horizontal lines*. What do *horizontal lines* look like? What kind of movement does a *horizontal line* make? What is a *horizontal line*?

Earlier we learned that *horizontal lines* are straight lines that move *right* and *left* or *side* to *side*. The words *right* and *left* are in red because those words help us to understand what movement the *horizontal line* makes.

The word *horizontal* comes from the Greek word *ορίζοντας* (orizontas) which means to mark out, or to bound. When we use the word horizon we often mean the straight line where the sun meets the earth. The *horizon* marks out where the sun rises and sets each day.

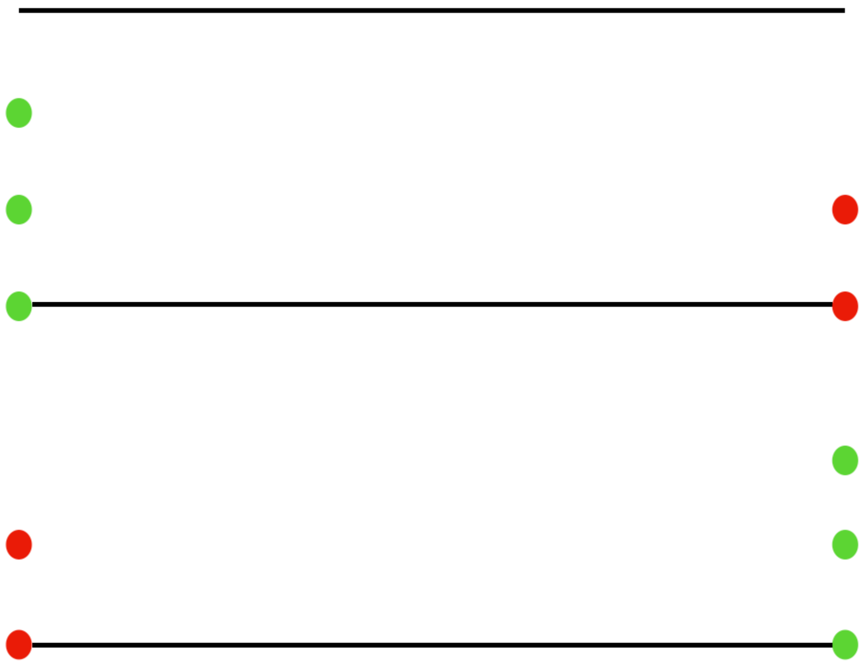
To draw a *horizontal line* the first step is to place a green point on a piece of paper as we see on the next page. This shows us where the *horizontal line* begins. Then to the *right* of this point we need to place a red point. This shows us where the *horizontal line* will end. Now beginning at the green point we need to draw a *horizontal line* that moves to the *right* and stops at the end point. This *horizontal line* runs to the *right* because the end point is to the *right* of the starting point.

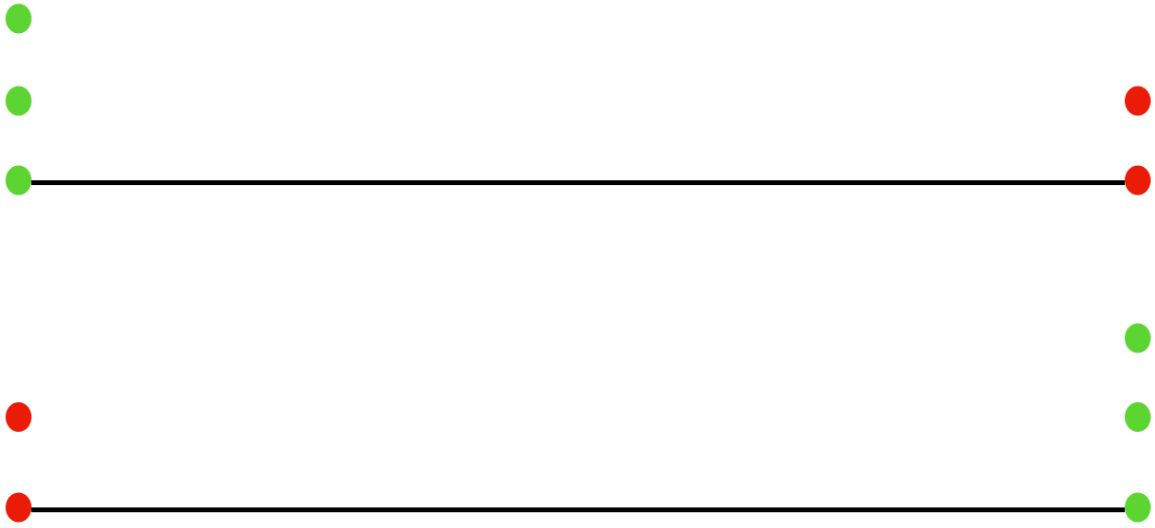
Now we will draw a *horizontal line* that moves to the *left*. To do this we need to place a green point near the right hand side of the page. Then to the *left* of this green point we will place a red point. Now beginning at the green point we need to draw a *horizontal line* that moves to the *left* and stops at the end point. We can say that this *horizontal line* runs to the *left* because its end point is to the *left* of its starting point.

Now we will make two more *horizontal lines*. These two *horizontal lines* need to be longer than the first two lines that we drew. We need to follow the same steps that we used when drawing the first two *horizontal lines*. One of the lines should run to the *right* and the other should run to the *left*. Both of these lines should be longer than the first two lines we drew.

Now if we compare the lines we drew, we can see that the the first two *horizontal lines* are shorter than second two *horizontal lines* that are longer.

Horizontal Lines





Drawing Oblique Lines

We will now learn how to draw *oblique lines*. How do *oblique lines* look different than vertical line and horizontal lines? What kind of movement do *oblique lines* make? Can *oblique lines* move in many different directions or do they only move in one direction like vertical and horizontal lines? What is an *oblique line?*

Oblique lines are lines that *tilt*, or *incline*. They can move in any direction except up or down or left to right.

The word o*blique* comes from the Latin word *obliquus* which means slanting, sidelong, indirect.

When drawing *oblique lines* it is important to be attentive to the words *under* and *above*, and *right* and *left*.

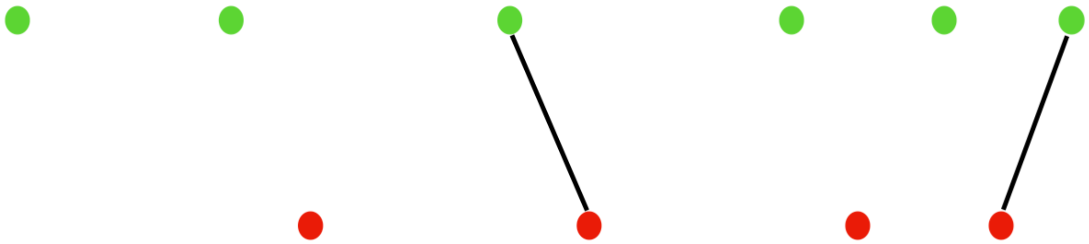
To draw an *oblique line* the first step is to place a green point for our starting point as we see on the next page . Now *under* this point and to the *right* of it we will place a red point. These points show us where the *oblique line* will begin and an end. It also shows us the movement of the line. Now starting at the green point we need to draw a line that moves toward and stops at the red point. We can see that this *oblique line* moves *downward* and to the *right*.

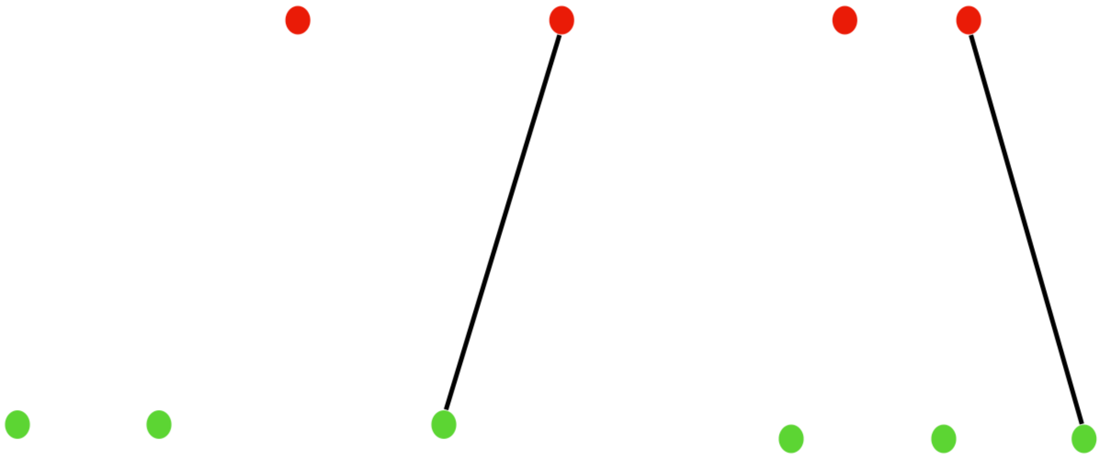
Now we need to place another green point on the page. This time *under* the green point and to its *left* we need to place a red point. Now starting at the green point we need to draw a line that moves towards and stops at the red point. We can see that this *oblique line* moves *downward* and to the *left*.

Now place another green point close to the bottom of the page. Then *above* this green point and to the *right* place a red point. Now starting at the green point we need to draw a line that moves towards and stops at the red point. This *oblique line* moves *upward* and to the *right*.

Now place a green point somewhere near the bottom of the page. Then *above* the green point and to the *left* of it place a red point. Now starting at the green point we need to draw a line that moves towards and stops at the red point. This *oblique line* inclines *upward* and to the *left*.

Oblique Lines





Angles

We will now learn about *angles*. What does an *angle* look like? Are *angles* different than lines? What geometric elements make an *angle*? What is an *angle*? Earlier we learned that an *intersecting point* shows us where two lines meet. *Angles* are formed when two straight lines that move in different directions meet and form an *intersecting point*.

There are three types of *angles* like there are three types of straight lines. The different *angles* are a *right angle*, an *acute angle*, and an *obtuse angle*. On the next page we can see examples of the different kinds of *angles*. What do they look like? In what way do the *angles* look different from one another?

The word *angle* comes from the Latin word *angulus* which means corner. If we look at the corner of a wall or a desk we can see an *angle.*

The first angle we will learn about is called a *right angle*. What does a *right angle* look like? How do we draw a *right angle*? A simple way to think about a *right angle* is to look at the capital letter T. The capital letter T is formed when a horizontal line and a vertical line intersect each other at a point. On both sides of the vertical line and below the horizontal line we can see two *angles*. They are called *right angles* because they are formed by straight lines and the two angles are equal to each other. Another example of a *right angle* is in the capital letter L. In this example we can see that the letter is formed with a vertical line and a horizontal line. We only see one angle, but we know that it is a *right angle* because it is formed with a horizontal and vertical line.

Another word that can be used to name the two lines that form a right angle is *perpendicular*. When two lines are *perpendicular* to each other they always form a *right angle*.

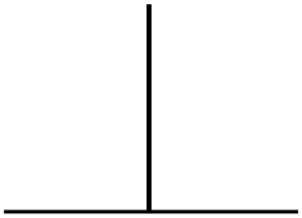
The word *right* that is used to name this kind of angle comes from the Greek word *ὀρεκτός (orektos)* which means stretched out, upright.

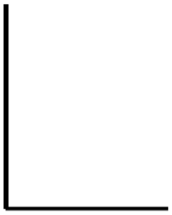
An *acute angle* is an angle that formed when two straight meet a point and form an angle that is *less* than or *smaller* than a right angle. The letters M and V give examples of *acute angles*. We can see that the vertical lines and oblique lines in the letter M form three *acute angles*. The oblique lines in the letter V also form an *acute angle*. The word *acute* comes from the Latin word *acutus* which literally means sharp or pointed. The end of a knife forms an *acute* angle.

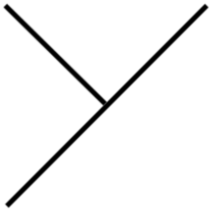
An *obtuse angle* is an angle that is formed when two straight lines meet at a common point and form an angle that is *greater* than a right angle. The letter Y has two *obtuse angles* and one *acute angle*. On the next page we can see examples of *obtuse angles*. The word *obtuse* comes from the Latin word *obtusus* which means blunted or dull.

Angles

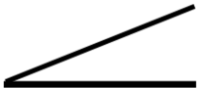
Right Angles

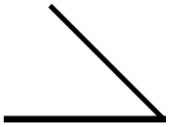


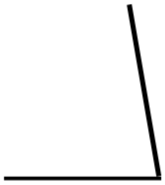




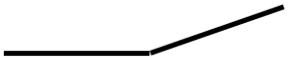
Acute Angles

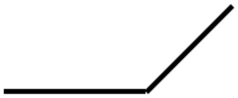


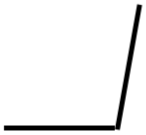




Obtruse Angles







Drawing Angles

We will now practice drawing *angles*. How many different types of angles are there? What do they look like? What *angles* are equal to each other? Which *angles* are smaller than a *right angle*? Which *angles* are larger than a *right angle*? These are questions we need to answer before we start to draw *angles*.

The first angle we will draw is a *right angle*. A r*ight angle* is formed by straight lines that form two equal *angles* at their intersecting point.

The first step to draw a *right angle* is to draw a horizontal line that will serve as the *base*. Then near the middle of the horizontal line we need to place an orange point. This is the point where the vertical line and horizontal line will intersect. Then directly above this point we need to place a blue point to show us where the vertical line will start. We are using different color points because we are using two different lines. Then starting with the blue point we make a vertical line that ends at the orange point. We can see that the two lines we drew have formed two *right angles*. Both *angles* are equal to each other.

Now we will form only one *right angle*. First we need to draw a horizontal line to be our *base*. Then above the starting point of the horizontal line we will place a pink point. This pink point shows us where the top point of the vertical line will be. Then beginning with the pink point we will draw a vertical line that will end at the green point. The vertical line and horizontal line intersect at the starting point of the vertical line. In this example we only drew one *right angle.* We know it is a *right angle* because it is formed by a vertical line and a horizontal line.

We will now draw an *acute angle*. Is an *acute angle* smaller or larger than a right angle?

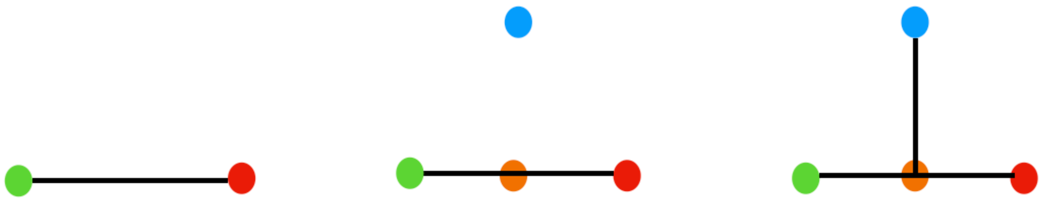
To form an *acute angle* we will use a horizontal line and an oblique line. First we will draw a horizontal line that will serve as the *base*. Then above the starting point of the horizontal line and to the right we place a blue point. Then starting with the blue point we draw an oblique line that ends at the starting point of the horizontal line. This intersecting point forms an *acute angle*.

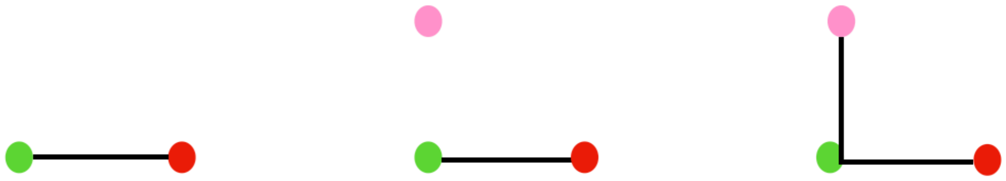
We will now draw an *obtuse angle.* Is an *obtuse angle* smaller or larger than a right angle?

To form an *obtuse angle* we will use a horizontal line and an oblique line. First we will draw a horizontal line for a *base*. Then above the starting point of the horizontal line and to the left we will place a blue point. Then starting with the blue point we will draw an oblique line that ends at the starting point of the horizontal line. This intersecting point forms an *obtuse angle*.

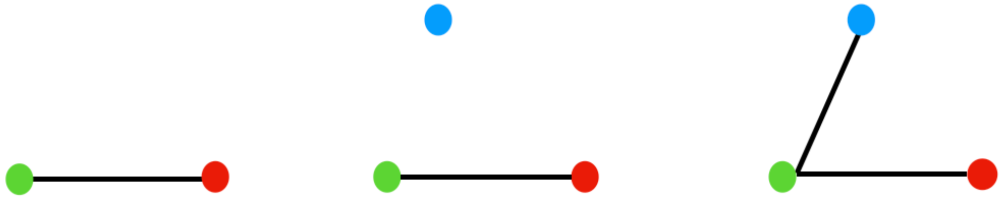
Drawing Angles

Right Angles

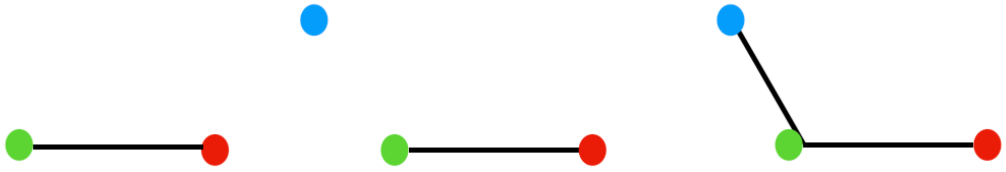




Acute Angle



Obtuse Angle



Parallel Lines

Now we will learn about *parallel lines*. What do *parallel lines* look like? What kind of lines can be *parallel*? What are *parallel lines*? If we look at the letter E we can see an example of parallel lines. In the letter E there are three horizontal lines that are *parallel* to one another. All three of the horizontal line move in the same direction. Are there any other letters that have *parallel lines*? The letter N also has *parallel lines*. The two vertical lines are *parallel* to each other. If the horizontal lines in the letter E went on forever they would never intersect each other at a point. If the vertical lines in the letter N went on forever they would never intersect each other at a point either.

Parallel lines are lines that move beside one another in the same direction, at the same angle, and have a space between them. The distance of the space between them can be large or small. If they went on forever they would never intersect each other. Straight lines are lines that can *parallel* to each other. There can be two lines that are *parallel* to each other or there can be several lines that are *parallel* to each other

The word *parallel* come from the Greek word *παϱάλληλο*, parállilo, which means beside one another.

If we look on the next page we can see two vertical lines that are *parallel* to each other. We can also see that there are four vertical lines *parallel* to each other.

We can see on the next page two horizontal lines that are *parallel* to each other. We can also see four horizontal lines that are *parallel* to each other.

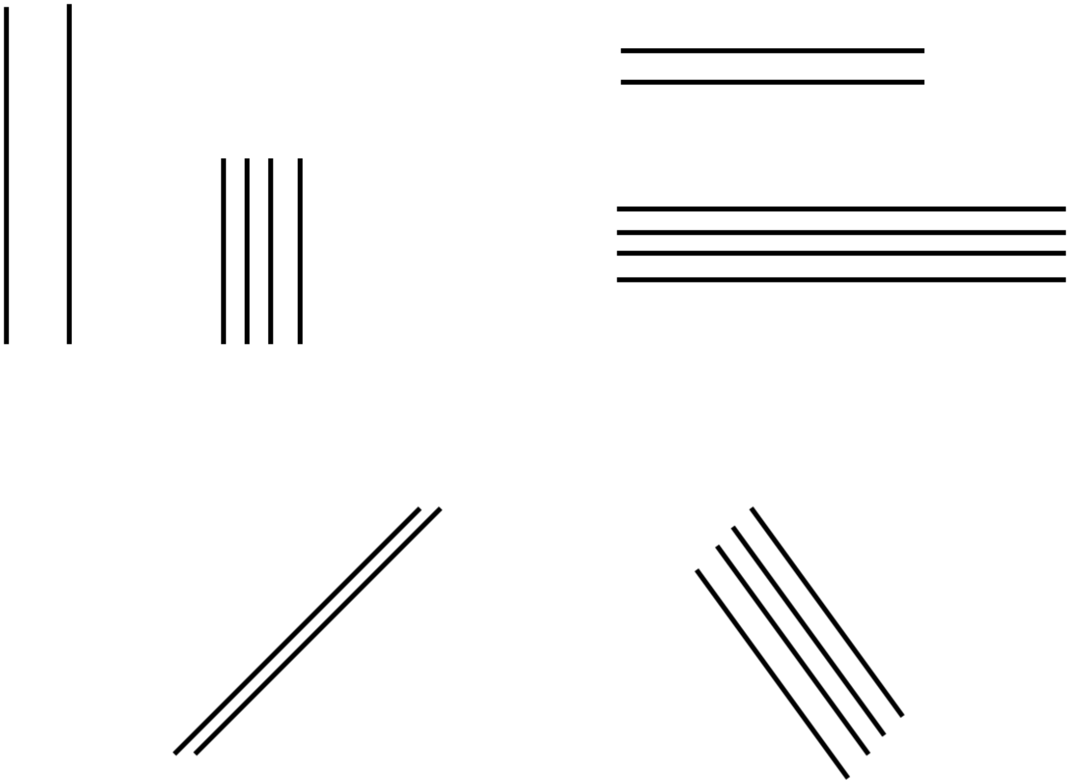
We can see on the next page we can see that two oblique lines can be *parallel* to each other. We can also see that three or more oblique lines can be *parallel* to each other.

To help us better understand *parallel lines* we can compare them with lines that are not *parallel* to one another. For example, a vertical line and horizontal line cannot be *parallel* to each other. Why not? Earlier we learned that when lines move in different directions they will meet at an intersecting point and form an angle. So a vertical line and a horizontal line will meet and form a right angle.

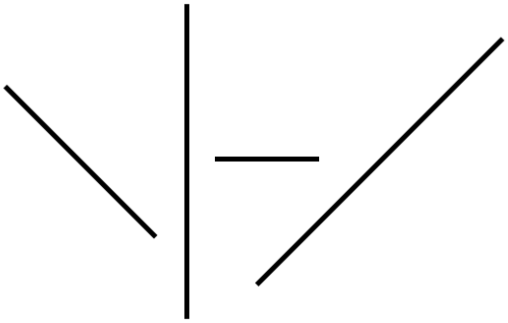
For lines to be *parallel* to each they other they must move in the same direction. They must always be beside each other, as the Greek word *παϱάλληλο* means.

Can a horizontal line and oblique line be *parallel*? They cannot be *parallel* to each other either because they will meet and form an acute angle or an obtuse angle.

Parallel Lines



Lines that are *not* parallel



Drawing Parallel Lines

We will now learn how to draw *parallel lines.* What do *parallel lines* look like? What kinds of lines can be *parallel*? Can two vertical lines be *parallel*? Can two horizontal lines be *parallel*? Can a horizontal line and an oblique line be *parallel*? Can a vertical line and an oblique line be *parallel*? We need know the answers to these questions before we begin to draw *parallel lines*.

The first kind of *parallel lines* we will draw will be using horizontal lines. First, we need to draw a horizontal line. Then we need to draw horizontal line that is under the first horizontal line and about the same distance as the first horizontal. We have now related two horizontal lines. These two horizontal lines are *parallel* to each other. They move in the same direction and if they go on forever they will never intersect each other.

Now we need to make one more horizontal line that is *parallel*. We can draw this line above or below one of the first two lines that we drew. We have now made a set of three *parallel horizontal lines*.

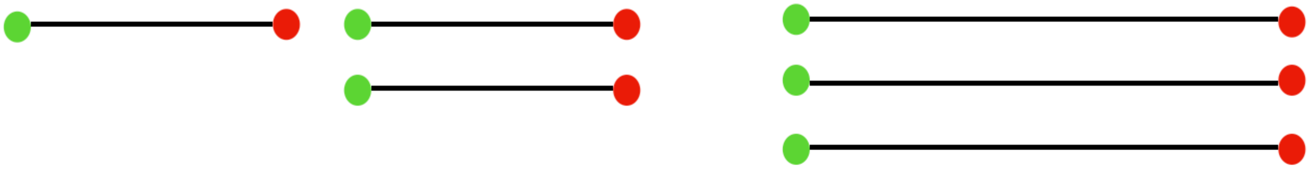
The second kind of parallel lines we will make will be using vertical lines. Vertical lines can also be *parallel* to each other. To do this we need to first draw a vertical line. Now to the right of the vertical line, we need to draw another vertical line that is same length. Now we have two *parallel vertical lines*. They move in the same direction.

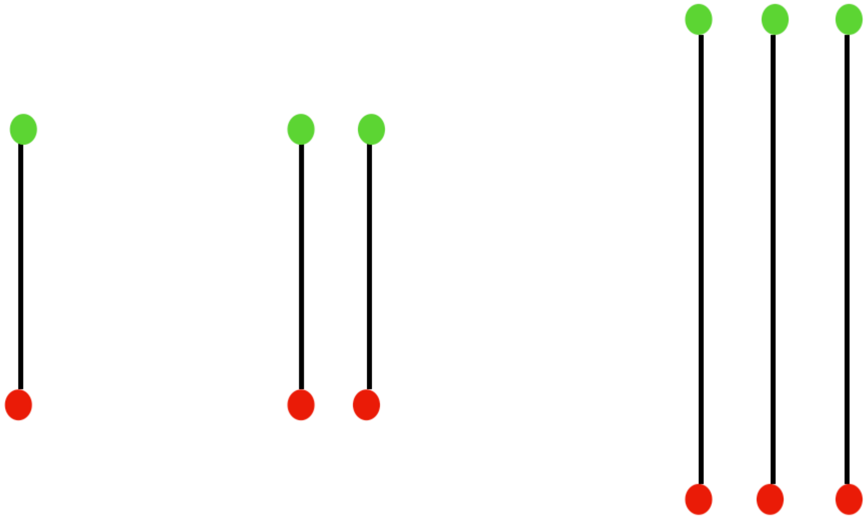
Now we need to make one more vertical line that is *parallel*. We can draw this line to the right or to the left of the first two lines that we drew. We have now made a set of three *parallel vertical lines*.

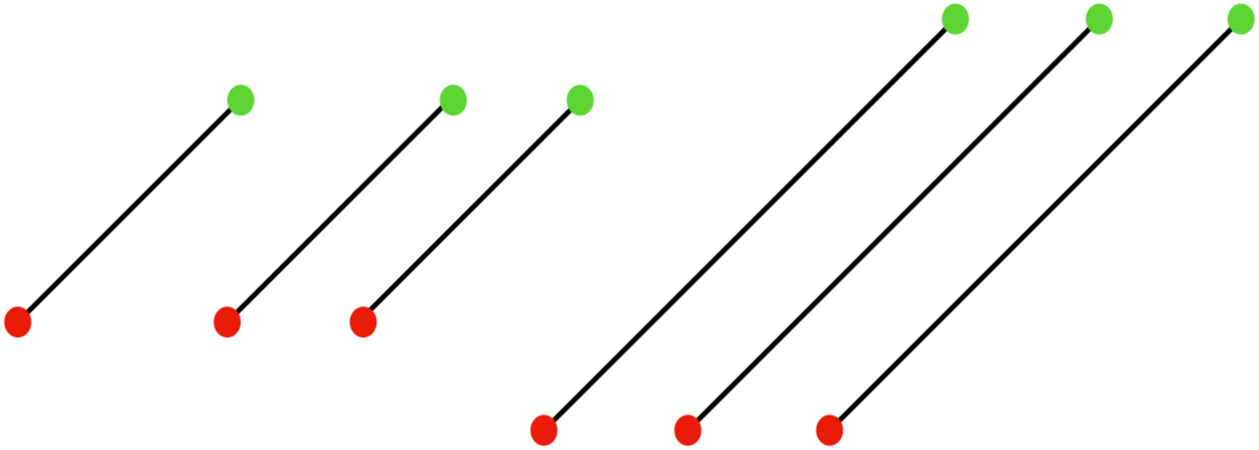
Parallel lines can also be made with oblique lines. To make *parallel oblique lines* we first will draw one oblique line. Then below and to the right of this oblique line we need to draw another oblique line that moves in the same directions. We have now drawn two *oblique parallel lines*. They move in the same direction.

Now we need to make one more oblique lines that is *parallel*. We can draw this line on either side of the first two lines we drew. We have now made a set of three *parallel oblique lines*.

Drawing Parallel Lines







Curved Lines

We have learned about the three different kinds of straight lines. Now it is time to learn about curved lines. What does a *curved line* look like? How does a *curved line* look different than a straight line? What kind of movements does a *curved line* make? Does a *curved line* have a different movement than a straight line? How does it move differently? What is a *curved line*?

A curved line is a line that moves in more than one direction. It is different than a straight line because a straight line only moves in one direction. It is similar to a straight line because a *curved line* also has a starting point and an end point. A *curved line* can have one or more curves between its starting point and end point. A *curved line* that has have one curve in it, can look like the letter C. A *curved line* that has more than one curve can like the letter S. A *curved line* can move up or down, or to the left or to the right between its starting point and end point.

The word *curved* comes from the Latin verb "*curvare*" which means to bend.

Earlier we saw that the letter S has two *curved* lines. There is a name for this kind of line. It is called a *reverse curve line* or an *s-curve* line because the two curves are on opposite sides. The *curves* move in two opposite directions.

How is a *curved line* different from an angle? A *curved line* is different than an angle because it does not intersect another line at a point to form an angle. A *curved line* is a single line that moves in different directions between its starting point and end point.

If we look at the *curved lines* on the next page we can see that one moves up from the starting point and at a certain point it begins to move down toward the end point. The point where the line begins to move down is called the *peak point*.

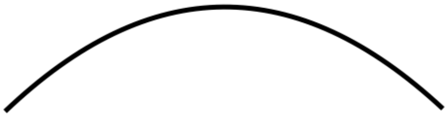
In the *curved line* on the next page we can the line moves down from the starting point and then when it reaches a certain point it begins to move upward toward the end point. The point where the line begins to move up is called the *base point*.

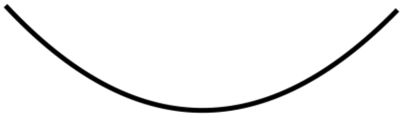
One of the *curved line* moves down and to the left from the starting point and then moves it the right and down as it reaches the end point. The moment the *curved line* changes direction and moves to right is called the *left most point* .

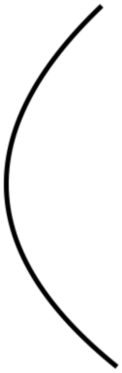
The other *curved line* moves down and to the right from the starting point and then moves to the left and down as it reaches the end point. The moment the *curved line* changes direction and moves to left is called *right most point*.

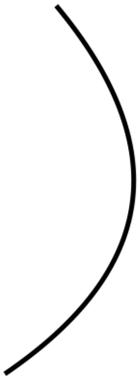
We can also see an examples of a *reverse curve line*. From its starting point it moves down and to the left and when it reaches the *left most point* it begins to move down and to the right. It moves down and to the right until it reaches the *right most point* when it begins to move down and to the left when it reaches its end point.

Curved Lines

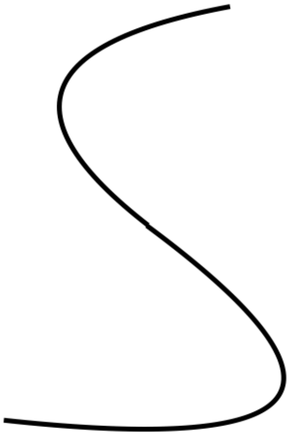








Reversed Curve



Drawing Curved Lines

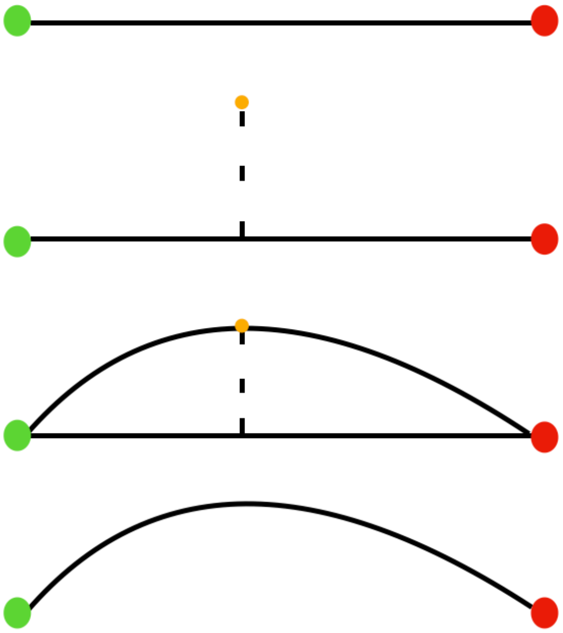
Drawing *curved lines* can be a little more difficult than drawing straight lines. In order to help us to learn how to draw *curved lines* we will use vertical and horizontal lines as guides to help us to draw them. What do *curved lines* look like? Do they have angles in them? What movements are in a *curved line*? Why are *curved lines* different than straight lines?

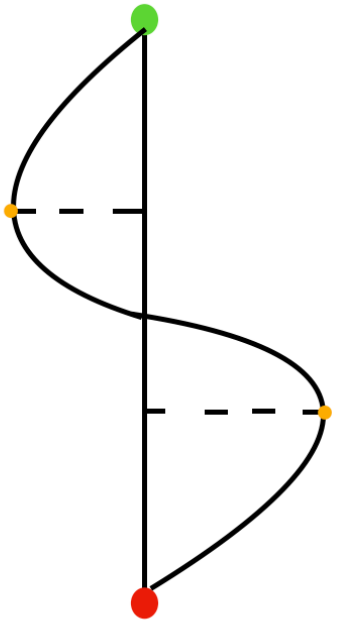
First, we need to draw a horizontal line. Then very lightly we need to draw a series of small vertical lines that start near the middle of the horizontal line and move upward. This will show us where the *peak point* will be. We can see the *peak point* in orange. Before drawing the curved line we need to remember to look at the starting point, then to move our eyes to the peak point, and from the peak point move our eyes to the end point. Once we have seen how all three points are related then we can begin to draw. We will begin at the starting point of the horizontal line and start to draw a line that gradually moves upward and to the right toward the *peak point* in orange. When the line reaches the *peak point* it will then start moving gradually downward and to the right until it reaches the end point on the horizontal line. Then we can erase the horizontal line and the small vertical line we made.

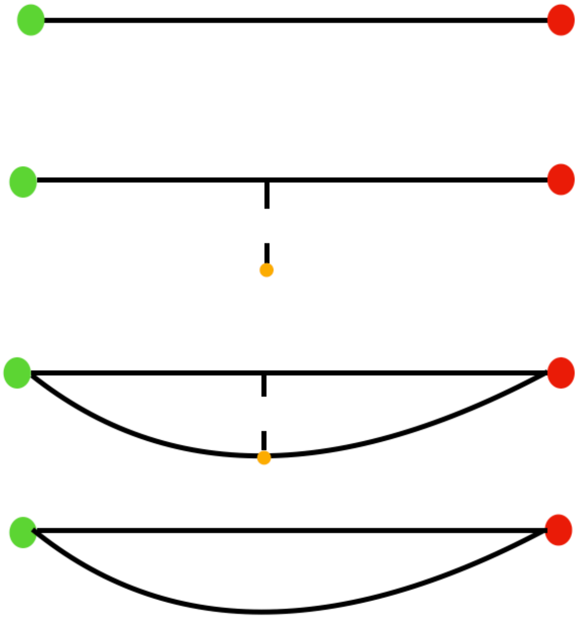
Now we need to draw another horizontal line. Then very lightly we need to draw a series of small vertical lines that start near the middle of the horizontal line and that move downward. This will show us where the *base point* will be. The *base point* is in orange. Before drawing the curved line we need to remember to look at the starting point, then to move our eyes to the *base point*, and from the *base point* move our eyes to the end point. Once we have seen how all three points are related then we can begin to draw. We will begin at the starting point of the horizontal line and begin to draw a line that gradually moves downward and to the right toward the *base point* in orange. When the line reachers the *base point* it will then start moving gradually upward and to the right until it reaches the end point on the horizontal line. Then we can erase the horizontal line and the small vertical lines we made.

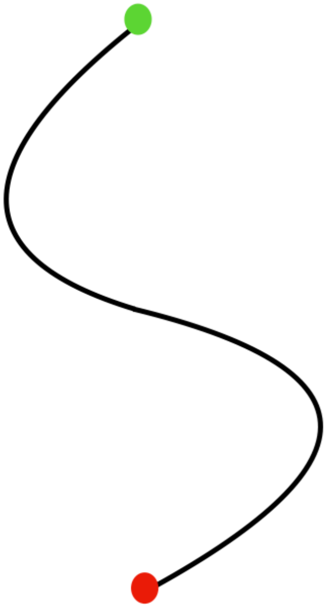
We can also draw a *reversed curved line* with the help of a vertical line. First we need to draw a vertical line. The we will draw small horizontal lines on different sides of the vertical line. One of these series of line will be near the top of the vertical line and will move to the left. The other series of small horizontal lines will be closer to the end point will move to the right. Then after looking at all of the points to see how they are related we will being to draw our line from the starting point of the vertical line. The first curve moves downward and to the left toward the *left most point*. When it reaches the *left most point* it changes direction and moves downward and to the right toward the *right most point*. When it reaches the *right most point* it changes direction again and moves downward and to the left toward the end point of the vertical line. Then we can erase the vertical line and the small horizontal lines.

Drawing Curved Lines









Mixed Lines

The next kind of line we will learn about is a *mixed line*. On the next page we can see some examples of a *mixed line*. What does a *mixed line* look like? How does it look different than a straight line and a curved line? What kind of movement is shown by a *mixed line*? What is a *mixed line*?

A *mixed line* is a line that is a combination of a straight line and a curved line. A *mixed line* has a starting point and an end point like every other line. What is different about a *mixed line* is that it has a straight movement and curved movement between its starting point and end point.

We can see an example of a *mixed line* in the lower case letter `t`. We can see that the letter has a horizontal line. The other line in the letter is *a mixed line*. The *mixed line* starts with a vertical line and moves downward and then it begins to curve upward and to the right.

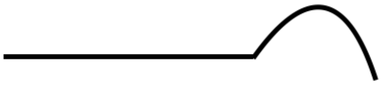
A *mixed line* can be made with a horizontal line and curved line, a curved line and a vertical line, or an oblique line and a curved line. A *mixed line* can move in every direction between its starting point and end point.

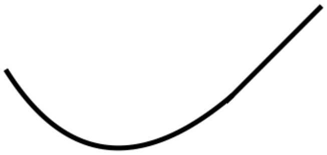
Implied Lines

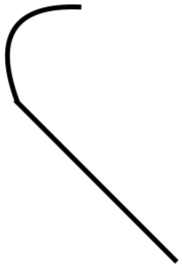
An *implied line* is the last kind of line we will learn about. On the next page we can see examples of *implied lines*. What does an *implied line* look like? How does it look different from every other line that we have learned about? What is an *implied line*? What are they used for?

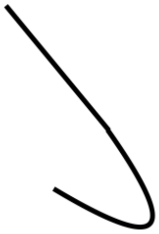
An *implied line* is a line that is formed only with points. The points in an *implied line* give as an idea of what kind of line may go on the page. An *implied line* can be any kind of line. It can be in the form of a vertical line, a horizontal line, an oblique line, a curved line, or a mixed line. An *implied line* can also be used to show where we should draw a line. So we can draw an *implied line* first because it is easier to erase points than a line.

Mixed Lines

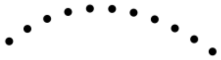


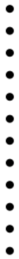


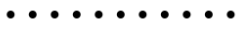


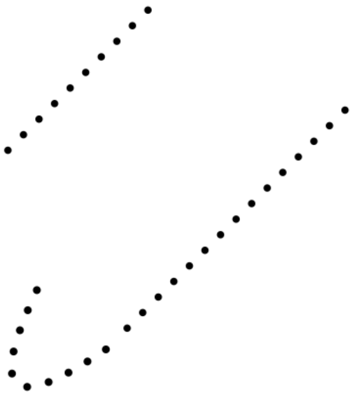


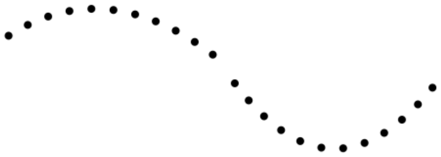
Implied Lines











Drawing Mixed Lines

Drawing *mixed lines* may seem a little confusing but if we remember the basics of how to draw a line it becomes easy.

We will draw a *mixed line* that is a combination of a horizontal line and a curved line. First we need to draw a horizontal line. Now where the end point of the horizontal line is we can begin to draw our curved line that will curve downward and when it reaches the right most point it will begin to curve to the left.

We can draw another *mixed line* that is a combination of a horizontal line and a curved line. This time our horizontal line will move to the left. At the end point of the horizontal line we can begin to draw a curved line that when it reaches the left most point will begin to move upward and to the right.

To draw a *mixed line* that has a vertical line and a curved line we can follow the same steps.

First we need to draw a vertical line. Then at its end point we can begin to draw a curved line that begins to move upward and to the right at its base point.

Now we can draw a vertical line that moves upward and at its end point it begins to curve and at its peak point begins to move to the left and downward.

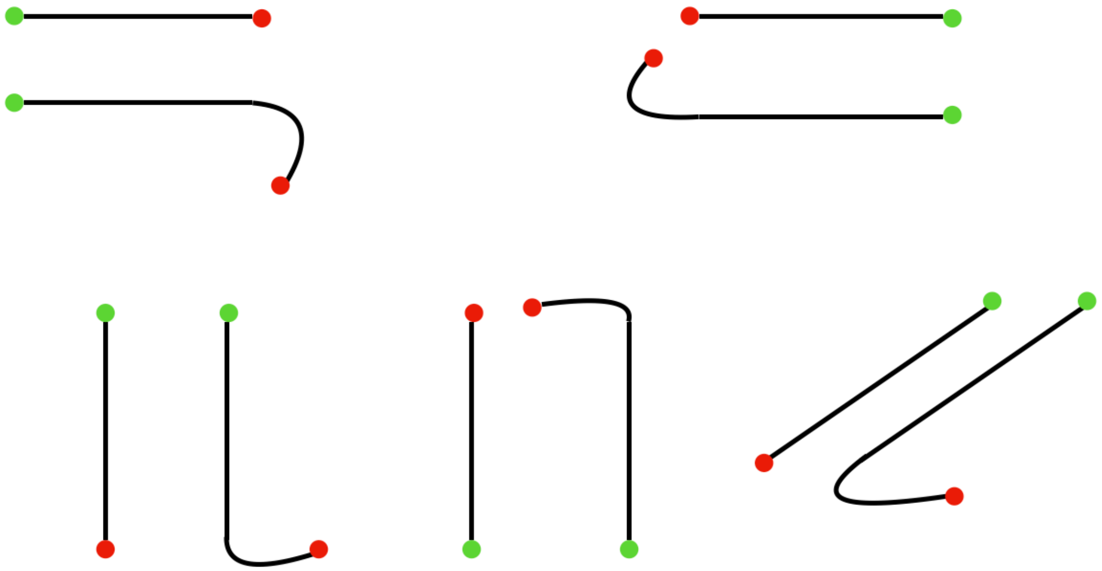
To draw a *mixed line* with an oblique line and a curved line we can draw an oblique line and at its end point draw a curved line that begins to move to the right and upward at its base point

Drawing Implied Lines

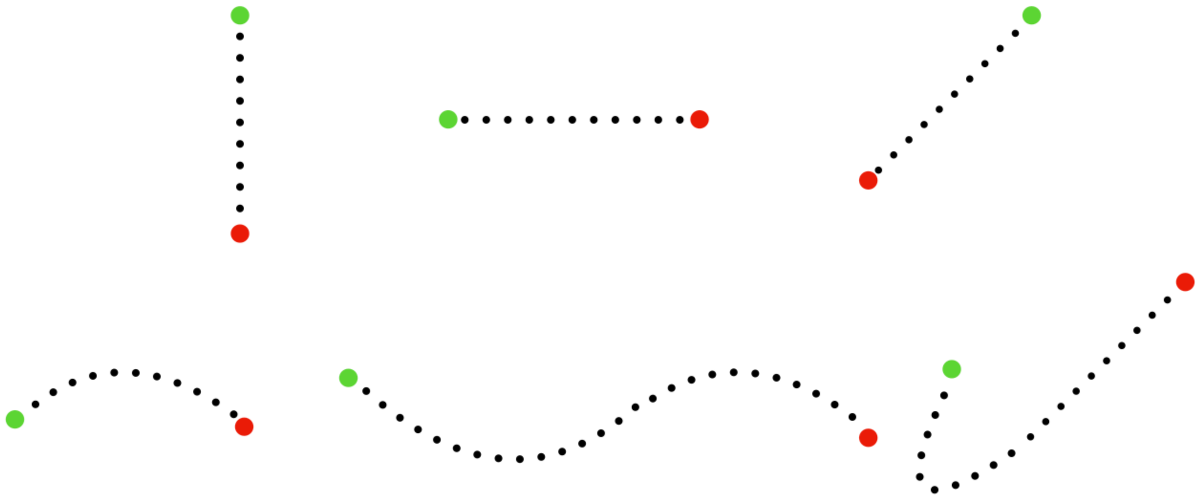
Implied lines are the last kind of lines that we will learn how to draw. In order to draw an *implied line* we follow the same steps that we used to draw the other lines. The only difference is that instead of connecting the starting point and end point with a continuous line we make points between he starting point and end point. The points can be drawn in the form of a vertical line, a horizontal line, an oblique line, and a mixed line.

Let’s try to draw all of the implied lines that we see on the next page.

Drawing Mixed Lines



Drawing Implied Lines



Review

What is a point? How do we describe what a point looks like? How do we draw one?

What is a line? What does a line start with and what does a line end with? How do we draw a line?

What is a straight line? What does a straight line start with and end with? How do we draw one?

What are the three different kinds of straight lines? How do we draw each one of them and describe what they look like?

What is an angle? What is a right angle? What is an acute angle? What is an obtuse angle?

How do we draw each of them?

How do we describe how the three angles look different from one another?

What kind of lines are perpendicular to each other? What kind of angles do they form? If perpendicular lines form two angles are two angles equal? How do we draw them?

What are parallel lines? Can a vertical line and a horizontal line be parallel to each other? Can three oblique lines be parallel to each other? How do we draw parallel lines?

What is a curved line? Does a curved line have a starting point and an end point? Can a line have more than one curve in it? What is a line called that has two curves in it that move in opposite directions? How do we draw a curved line?

What is a mixed line? What two kinds of lines are used to form a mixed line? How do we draw a mixed line?

What is an implied line? How do we draw an implied line?

Geometric Figures

Circles, Triangles, Quadrilaterals, and Ellipses

Introduction to Geometric Figures

The word figure in geometry means the same thing as the word shape. For example a circle is a *geometric figure*. We sometimes say a coin is in the shape of a circle. What are the different *geometric figures* that we will learn about? Why do we use them? How do we draw them? On the next page we can see examples of each of the *geometric figures* we will learn about in this book. What do each of them look like? What makes them look different? Which ones are made with curved lines, and which ones are made with straight lines?

Geometric figures are formed by using lines and points. Why did we start learning about points, lines, and angles? We learned about them first so that we can learn to draw shapes. Everything we see in the world can be drawn by using the different kinds of lines that we learned about.

There are many different kinds of *geometric figures*. The ones that we are going to be learning about are the *circle*, *triangles*, *quadrilaterals*, and *ellipses*.

A circle is the first *geometric figure* that we will learn about. It is the first shape we will learn about because it is perfect. It has no beginning and no end. It made by using a continuous curved line. It is the only shape that doesn't have a beginning and an end. There is also only one kind of circle. A circles is a curvilinear figure because it is made with a curved line.

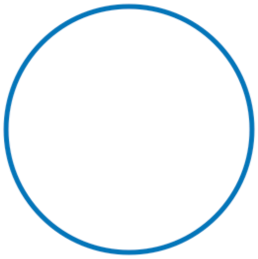
The triangle is the next *geometric figure* that we will learn about. It is a shape that has three sides, and three angles. It is formed with straight lines. It was the basis for building the pyramids in Egypt. It is a rectilinear figure because it is made with straight lines.

The quadrilateral is the next *geometric figure* that we will learn about. It has four sides and four angles. It is also formed using straight lines. Many buildings and homes are based on the quadrilateral. It is also a rectilinear figure because it is made with straight lines.

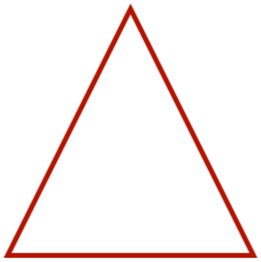
An ellipse is the last *geometric figure* we will learn about. It is like a circle because it is formed only with a curved line, but it is different because one of its parts is longer and the other is shorter. It is a curvilinear figure because it is made with a curved line.

Introduction to Geometric Figures

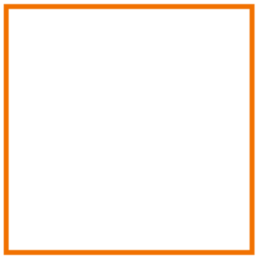
Circle



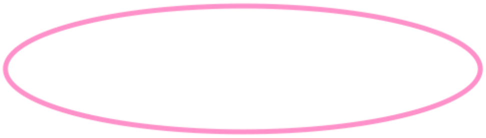
Triangle



Quadrilateral



Ellipse



The Circle

The first shape we will learn about is a *circle*. What does a *circle* look like? What kind of lines do we see in a *circle*? What is a *circle*?

The word *circle* comes from the Latin word "circulus" which means small ring.

Many things that we use in day to day life are in the shape of a *circle*. What are some things that we experience that are in a *circle* shape? For example a coin is in the shape of a *circle*. If you look at your neighbors eyes they are also a *circle* shape.

A *circle* is curvilinear figure that is a continuous curved line. It has no starting point or end point. The word curvilinear means that the geometric figure is formed with a curved line.

The name of the curved line that makes the circle shape is called the *circumference*. On the next page the *circumference* is in red.

The *center point of the circle* is the point from which a circle is formed. On the next page the *center point* is in green.

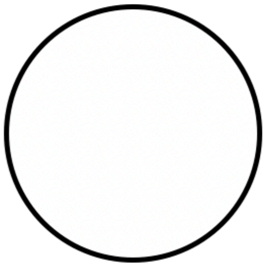
The *radius* is the name of the straight line that moves from the center point to the circumference.

The *diameter* of a circle is the distance of a straight line that moves from one side of the circumference to the opposite side of the circumference passing through the center point.

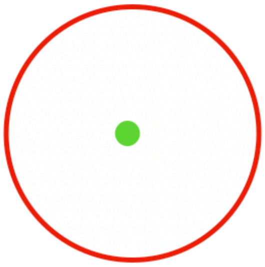
A *semicircle* is half of a circle. A semicircle is formed when we draw the diameter because we divide the *circle* into two equal parts.

A *quadrant* of a circle is formed when we draw a vertical diameter and a horizontal diameter. The circle is divided into *four* parts. When we cut a pizza into four parts we use a horizontal diameter and a vertical diameter so that there are *four* equal pieces for everyone.

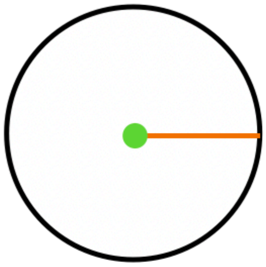
Circles



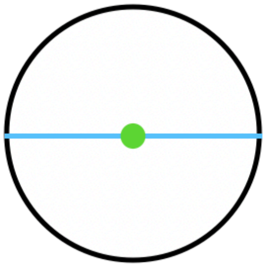
Circumference and Center point



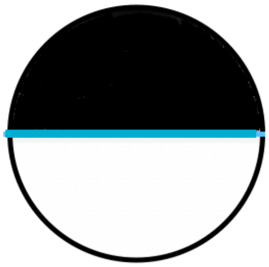
Radius



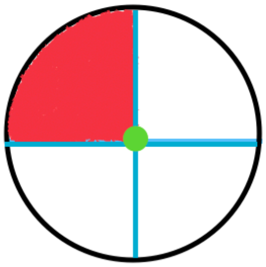
Diameter



Semi Circle



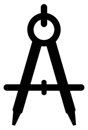
Quadrant



Drawing a Circle

In order to draw a *circle* we can use something that looks like a *circle*, for example a coin. We can also use something that is called a compass.

Here we can see an image of a compass:



A compass is is used to draw *circles*. This kind of compass is different than the compass we saw earlier. Even though the same word is used they mean two different things. The other compass was used to help understand the movements of lines by seeing what direction they moved in. For example, a vertical line moves north and south, a horizontal line moves east to west, and an oblique line can move in any direction except north, south, east, or west. The other type of compass is used to draw *circles*.

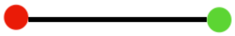
A compass has what is called two legs. One of the legs often has a metal point. The other leg has an adapter to place a pencil, or a piece of graphite that is inside the leg of the compass. The metal point will show where there center point will be and the leg with the pencil or graphite will be used to draw the circumference.

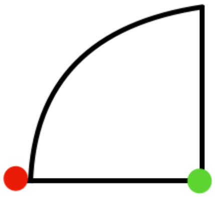
To form our first *circle* we need to decide on the distance between the two legs of the compass. This distance will the be the *radius* of our *circle*. The *radius* is the distance from the center point of the *circle* to a point on the circumference. We will place the leg of the compass with the metal point to be the center of our *circle* and place the other leg as the starting point of the circumference. When both of the points are on the paper simply simply spin the compass from the top to form our *circle*.

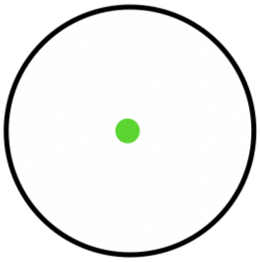
It is good to practice making different size *circles*. On the next page we can see *circles*, *semicircles*, and quadrants of *circles*.

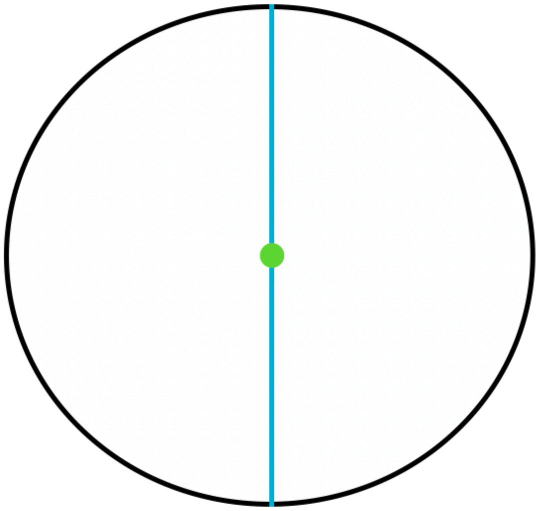
What type of line is used to form a *circle*? What is the circumference? Does the radius start at the center point of a *circle*? Does a diameter move through the center of a *circle*? What lines are used to divide a *circle* in half? How do you find the quadrant of a *circle*?

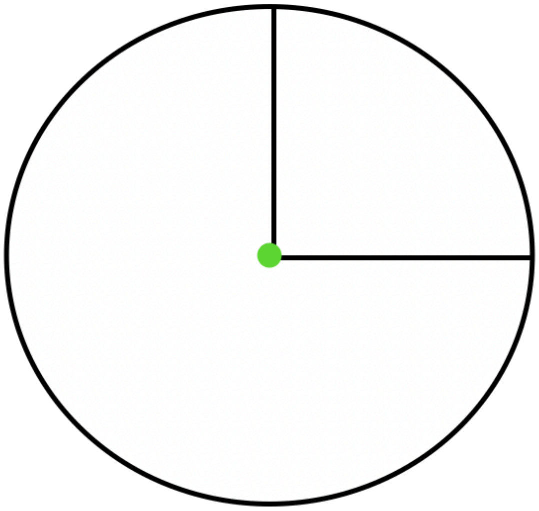
Drawing Circles

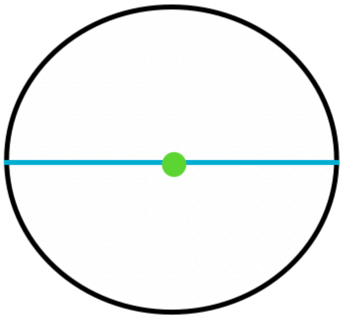












Drawing Circles Freehand

Drawing *circles* freehand, meaning without the help of a compass is somewhat difficult. To help us in this endeavor we will use horizontal and vertical lines like we did when we learned how to draw curved lines.

First of all we need to form a cross by using a vertical line and horizontal line that are equal in length. The vertical and horizontal lines need to intersect each other at the middle point.

Next beginning at the top of the vertical line we can make a curved line that moves from the starting point of the vertical line to the starting point of the horizontal line. The curved line moves downward and to the left. The starting point of the horizontal line is the left most point of the curve.

We then continue to make our curved line move from the starting point of the horizontal line to the end point of the vertical line. The curved line moves downward and to the right. The end point of the vertical line is the base point of the curve.

From the end point of the vertical line we continue our curved line to the end point of the horizontal line. It moves upward and to the right until it reaches the right most point which is the end point of the horizontal line.

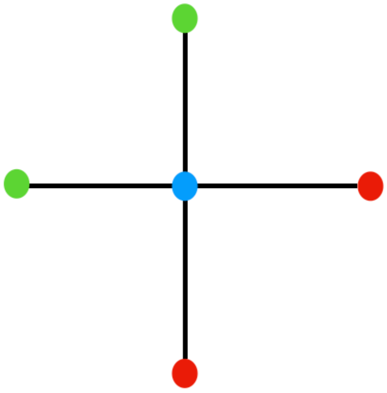
Finally we draw the last quadrant of the circle by letting the curved line move from the end point of the horizontal to the starting point of the vertical line. It moves upward and to the left until it reaches the peak point of the curve.

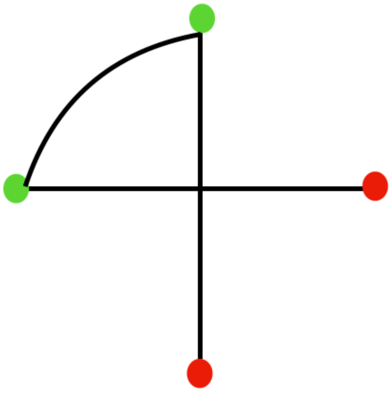
We can think of drawing our *circle* by using four curved line that when they are connected become a *circle*.

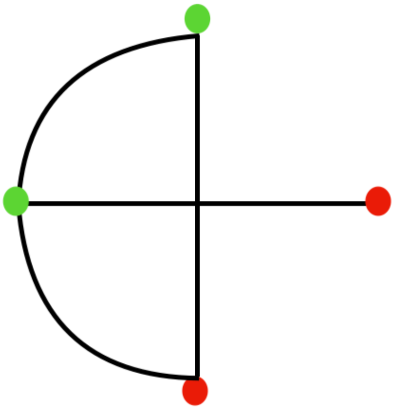
Now we need to review our curved line to see if it is in the shape of a *circle*. It is probably not drawn perfectly. That is ok. If we need to erase parts of the circumference and make corrections so that our circumference looks true we should do that. We need to get the circumference as close as possible so that it looks like a *circle*.

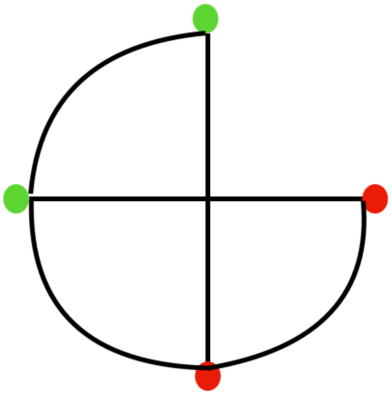
It is ok if the *circle* does not look perfect. The idea is to begin to understand the steps we can take to draw *circles*.
ddd

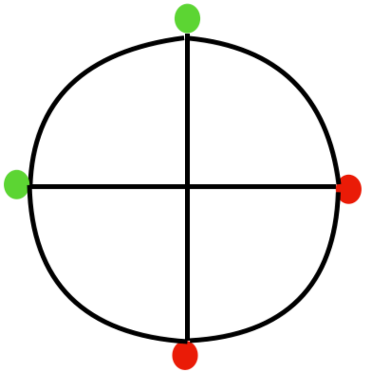
Drawing Circles Freehand











Ellipses

The next geometric shape we will learn about is an *ellipse*. What does an *ellipse* look like? What parts are longer and what parts are shorter on an *ellipse*? What is an *ellipse*?

The word *ellipse* comes from the Greek word *έλλειψη* (élleipsi) which means to fall short or to leave out.

An *ellipse* is a curvilinear figure like a circle.

In order to help us understand what an *ellipse* is we can take a quarter or anything else that is a circle shape and hold it in between our fingers. If we place it directly in front of our eyes we can see that it looks like a circle. However, if we begin to tilt the coin towards us it no longer looks like a circle. It becomes an *ellipse*. If hold the quarter in front of our eye again and this time turn the quarter away from us it no longer looks like a circle. It becomes an *ellipse*.

What happens? Why do we see an *ellipse* instead of a circle when it turns toward or away from us?

If we observe closely we cans see that when we hold a quarter directly in front of us the entire circumference is the same distance from our eyes. However, if we tilt the quarter away from us the top most point is farther from our eyes, and the bottom most point is closer to our eyes.

If we tilt the quarter in the other direction, the top most point is closer to our eyes and the bottoms most point is farther from our eyes. On the next page we can see an example of this.

The same thing happens if we tilt the quarter to the left or to the right.

In the example on the next page we can see a blue line and a red line. The blue line is a vertical line. The red line is a horizontal line. The vertical line is called the *vertical axis*. The horizontal line is called the *horizontal axis*.

The *vertical axis* shows us the height of something. It shows how tall something is. It shows an up and down movement. The *horizontal axis* shows us the width of something. The width shows us how wide something is. It show a movement that goes side to side, right to left.

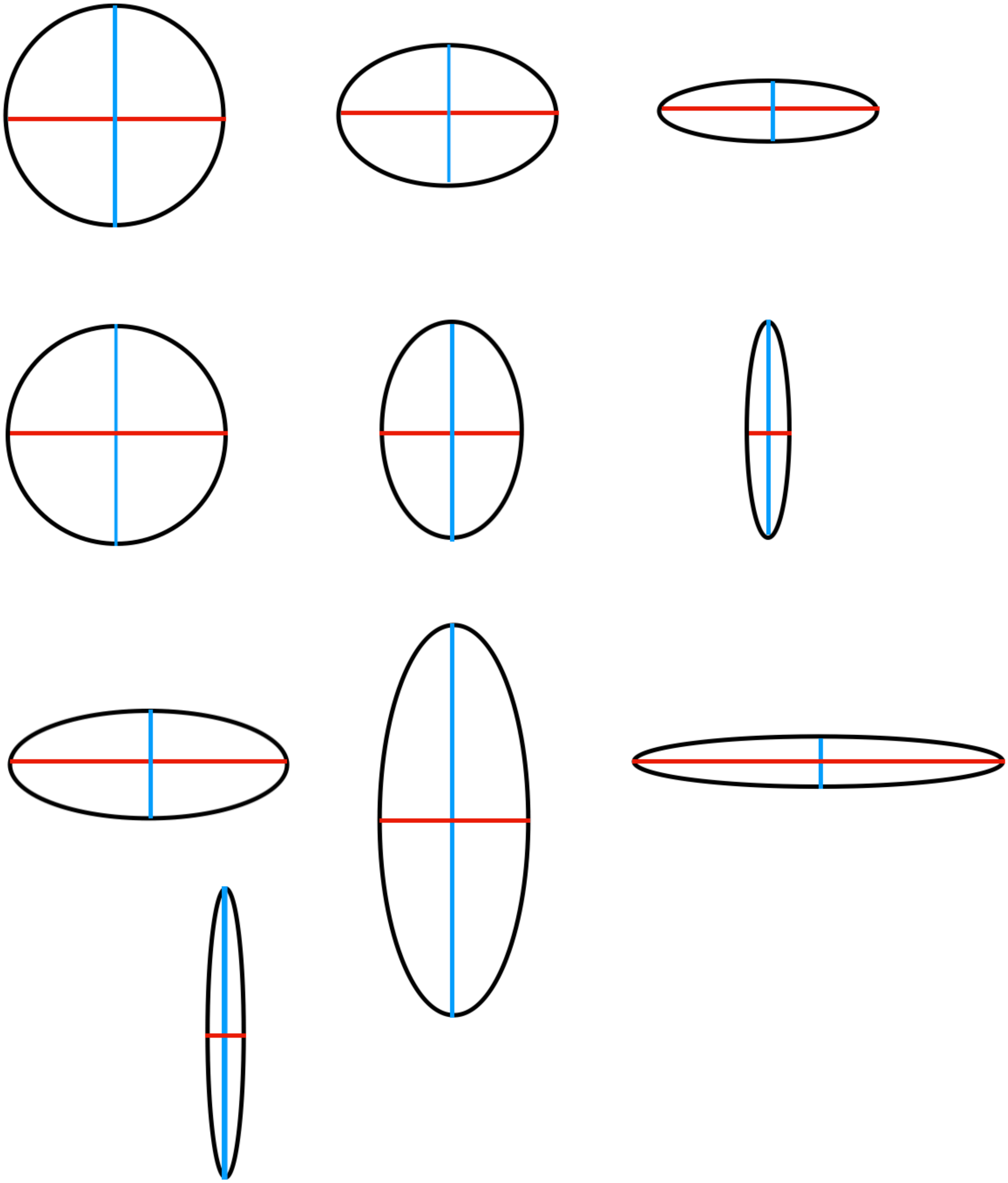
An *ellipse* always has a vertical axis and a horizontal axis.

In an *ellipse t*here will always be a longer axis and a shorter axis.

The *longer axis* is called the *major axis* and the *shorter axis* is called the *minor axis*.

If we look on the next page can we point out the *ellipses* that have the horizontal axis as a *major axis*? Can we see the ellipses that have the *vertical axis* as the *major axis*?

Ellipses



Drawing Ellipses

We will now learn how to draw *ellipses*. What does an *ellipse* look like? How does it look different than a circle? What is an *ellipse*? An *ellipse* will always have an axis that is longer and an axis that is shorter. In a circle the the vertical axis and horizontal axis are the same length.

In order to draw an *ellipse* we need to first of all establish our *major axis* and our *minor axis*. To do this we will form a horizontal line that will be our *major axis*. Then we will draw a vertical line that is shorter than the horizontal line. It will be the *minor axis*. The vertical and horizontal lines need to intersect each other at their middle points.

Then beginning with the starting point of the horizontal line we can draw a curved line that moves upward and to the right until it touches the top point of the vertical line and then at the top begins to move downward and to the right until it reaches the end point of the horizontal line.

We then continue to draw the curved line from the end point of the horizontal line to the end point of the vertical line. When it reaches the base point it then beginsto move upward and to the left until it reaches to the starting point of the horizontal line. Now we can erase the *horizontal axis* and the *vertical axis*.

The *ellipse* should always be curving. We should not see an angle on the *ellipse*.

In this example the horizontal line is the *major axis* and the vertical line is the *minor axis*.

Now we will draw an *ellipse* with the vertical line as the *major axis* and the horizontal line as the *minor axis*.

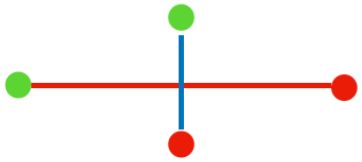
First we need to draw a vertical line and a horizontal line that intersect each other at the middle point. The vertical line needs to be longer than the horizontal line because it is the *major axis*. The horizontal line is the *minor axis*.

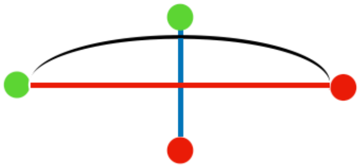
Then beginning with the starting point of the vertical line we can begin to draw our curved line downward and to the left until it reaches the the starting point of the horizontal line, the left most point. Then the curved line begins to move downward and to the right until it reaches the end point of the horizontal line, the base point.

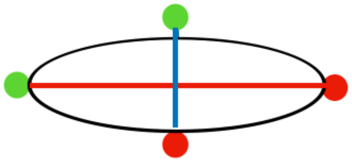
Next the curved line then begins to move upward and to the right until it reaches the end point of the horizontal line, the right most point. It then continues to move upward and to the left until it reaches the top of the vertical line, the peak point. Now we can erase the horizontal axis and the vertical axis.

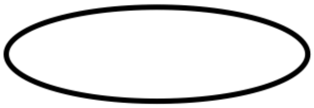
The *ellipses* that we drew should remind us of the way the appearance of the coin changed when we tilted away from us or towards us.

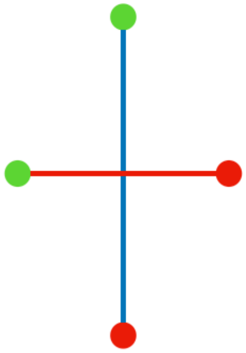
Drawing Ellipses

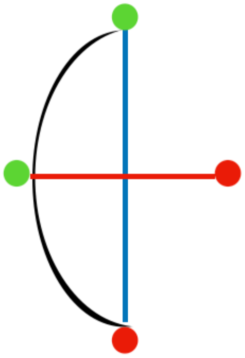


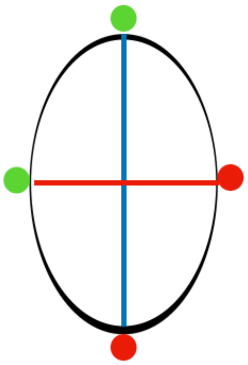


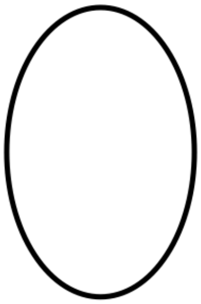












Review

What is a circle? Can we name at least three different things that look like a circle? Can we draw a circle using a compass? Can we draw a circle freehand? What steps are used in drawing freehand circle?

What is a curvilinear figure? What kind of line is used to form a curvilinear figure?

Where does the word circle come from and what did it originally mean?

What is the line around the circle called?

What is a radius?

What is a diameter?

What is a semicircle and how is it formed?

What is a quadrant of a circle and how is it formed?

What is an ellipse? Why does an ellipse look different than a circle?

What is the horizontal axis? What is the vertical axis?

What is the major axis? What is the minor axis?

What line shows us the height? What line shows us the width?

Triangles

Triangles

The next geometric figure or shape we will learn about is called a *triangle*. What does a *triangle* look like? How does it look different than a circle? What kind of lines does a *triangle* have? What kind of angles does a *triangle* have? How many lines and how many angles does it have? What is a *triangle*?

A *triangle* is a shape that is formed with three straight lines. In this way it is different than a circle. A circle is formed with a curved line and a *triangle* is formed with straight lines. Another way that a *triangle* is different from a circle is that a *triangle* has points and angles. It is also different because there a different kinds of *triangles*, but there is only one circle.

The horizontal line of the *triangle* is called the base, and the other two sides are called legs.

When a geometric figure is formed with straight lines it is called a *rectilinear figure*.

The word *triangle* comes from the Latin word "*triangulum*", which means three angles. The prefix "*tri*" means three, and the word "*angulum*" means angle.

The different *triangles* receive their names based on the length of their sides and based on their angles.

A *triangle* whose three sides are equal is called an *equilateral triangle*. The base and the legs all have the same distance. The word equilateral comes from a Latin word "*aequilaterus*" that means equal sided. '*Aequus*' means equal, and '*latus*', means side.

A *triangle* which has only two sides that are equal is called an *isosceles triangle*. The word isosceles comes from the Greek word "*ισοσκελής*"*(isoskelēs)* which means having equal legs. The word "*isos*" means 'equal' and "*skelos*" means 'leg'. An *isosceles triangle* is a triangle whose two legs are the same length, but the length of the base is different.

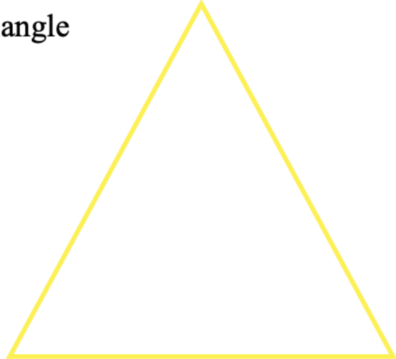
A *triangle* that does not have any of its sides equal is called a *scalene triangle*. The word scalene also comes from the Greek language. The Greek word "*σκαληνός*", (skalēnos) means unequal. None of the straight lines have the same distance. The legs and the base are different distances.

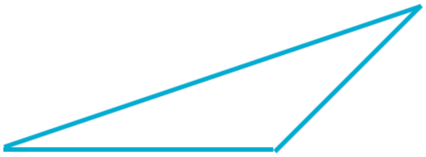
A *triangle* that has a right angle it is called a *right triangle*.

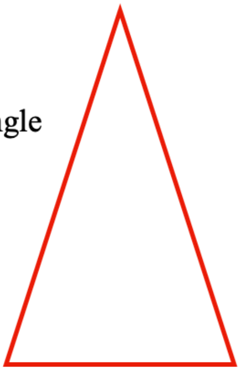
A *triangle* that has three acute angles is called an *acute triangle*.

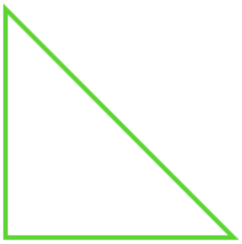
A *triangle* that has an obtuse angle is called an *obtuse triangle*.

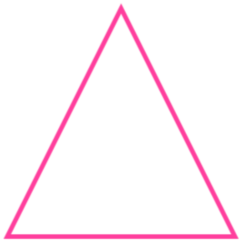
Triangles

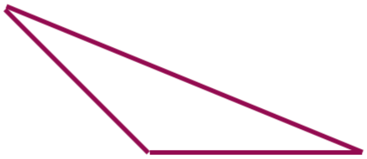

Equilateral Triangle


Scalene Triangle


Isosceles Triangle


Right Triangle


Acute Triangle


Obtuse Triangle

Drawing Triangles: Equilateral Triangles

The first triangle we will learn to draw is an *equilateral triangle*. What does an *equilateral triangle* look like? What is an *equilateral triangle*? An *equilateral triangle* is a triangle whose three sides all have the same distance. The base and the two sides have an equal distance. The three angles in an *equilateral triangle* are also equal to each other.

The first step in drawing an *equilateral triangle* is to establish its base. The base is the horizontal line on which the figure rests.

First we need to draw a horizontal line with a green point to indicate where it starts and a red point to indicate where it ends. The base is in orange.

Then we need to find the halfway mark. This can be done with a compass or a ruler. On the next page we can see this illustrated with a small blue vertical mark on the first horizontal line.

Next, from the halfway mark we will draw a vertical line that is equal in length to the horizontal line.

What type of angles do these two lines form? What are these lines called? Earlier we learned that if a straight line stands on another straight line and forms two equal angles they are right angles. The two lines that form a right angle are called perpendicular lines.

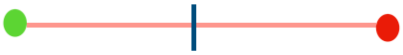
Then from the top of the vertical line we draw an oblique line in yellow that goes to the starting point of the horizontal line that is green, and another oblique line in yellow that starts from the top of the vertical line and runs to the end point on the horizontal line that is red.

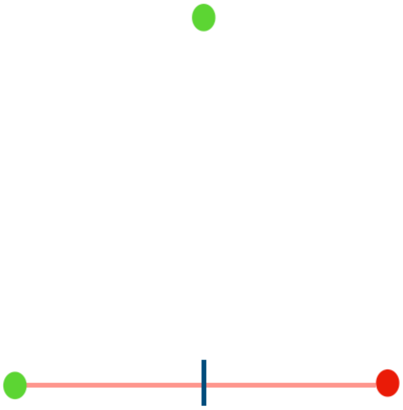
Now we can erase the vertical line so that all that remains is an *equilateral triangle.*

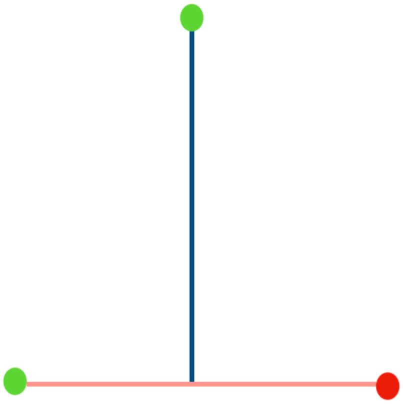
An *equilateral triangle* is a triangle whose three sides are the same distance and whose three angles are equal to one another.

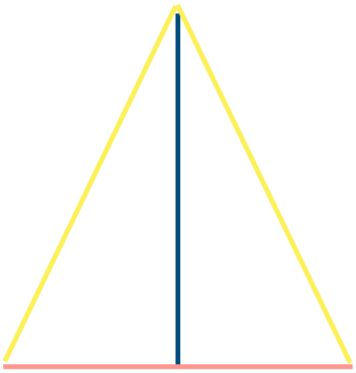
Drawing Equilateral Triangles

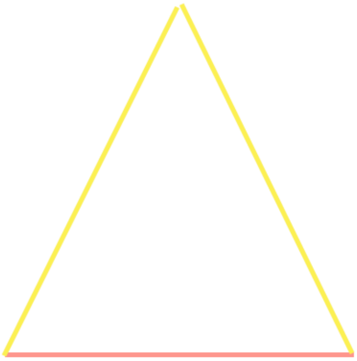
Horizontal Line with
Halfway Mark











Drawing Triangles: Isosceles Triangle

We will now learn how to draw an *isosceles triangle*. What does an *isosceles triangle* look like? How does an *isosceles triangle* look different than an *equilateral triangle*? What is an *isosceles triangle*?

An *isosceles triangle* is a triangle that has only two sides that are equal. The base is a different length than the two sides.

The first step in drawing an *isosceles triangle* is to establish its base. The base is a horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

The next step is to find the halfway mark. This can be done with a compass or a ruler. On the next page you can see this illustrated with a small blue vertical mark on the first horizontal line.

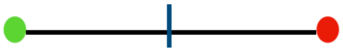
Next, from the halfway mark we will draw a vertical line that is *longer* in length than the horizontal line.

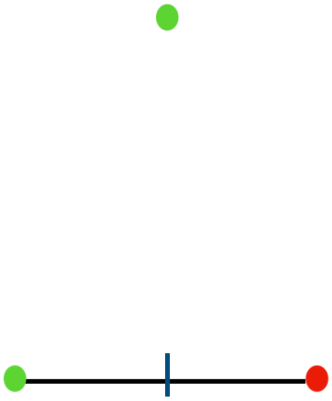
Then from the top of the vertical line draw an oblique line in yellow that goes to the starting point of the horizontal line. The draw another oblique line in yellow that starts from the top of the vertical line and runs to the end point on the horizontal line.

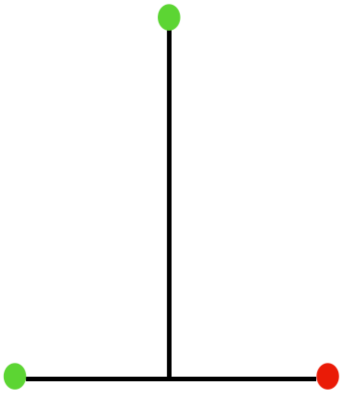
Now erase the vertical line so that all that remains is an *isosceles triangle.*

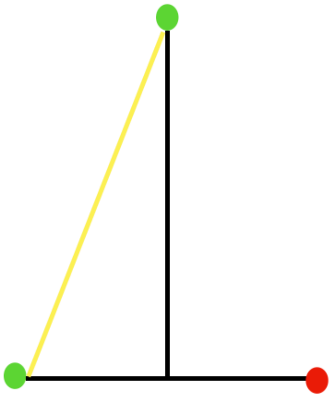
An *isosceles triangle* is a triangle whose two legs are equal to each other, but whose base is a different length.

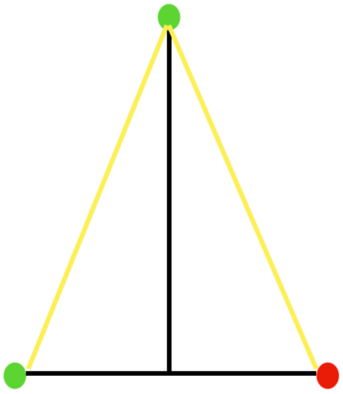
Drawing Isosceles Triangles

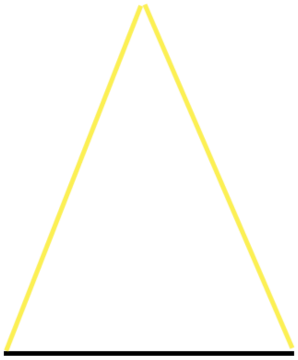












Drawing Triangles: Scalene Triangle

We will now learn how to draw an *scalene triangle*. What does an *scalene triangle* look like? What is an *scalene triangle*? How does an *scalene triangle* look different than an *equilateral triangle* and an *isosceles triangle*?

A *scalene triangle* is a triangle that does not have any sides that are equal.

The first step in drawing an *scalene triangle* is to establish its base. The base is a horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

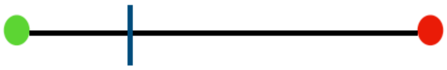
Then we need to make a mark on the horizontal line that is close to the starting point. Above this mark we need to place a green point. From this green point we need to draw a vertical line that intersects with the base.

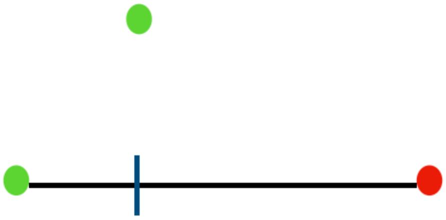
Then from the top of the vertical line we need to draw an oblique line in orange that goes to the starting point of the horizontal line. Next we need to draw another oblique line in blue that starts from the top of the vertical line and runs to the end point on the horizontal line.

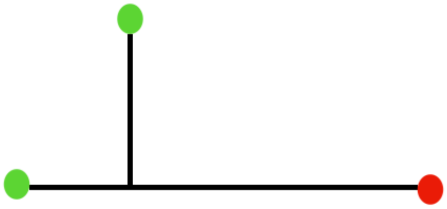
Now we can erase the vertical line so that all that remains is an *scalene triangle.*

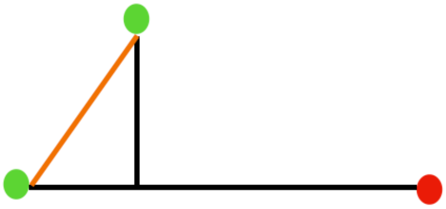
An *scalene triangle* is a triangle whose every side is a different length. The base and both legs are different distances.

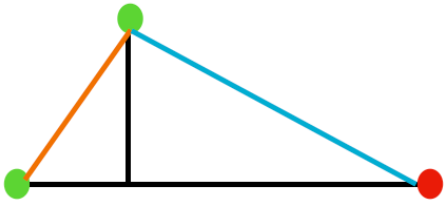
Drawing Scalene Triangles

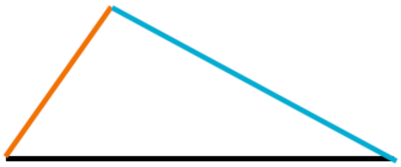












Drawing Triangles: Right Triangle

We will now learn how to draw an *right triangle* or a *right angled triangle*. What does a *right angle triangle* look like? How does a *right angle triangle* look different than an *equilateral triangle,* an *isosceles triangle,* and an *equilateral triangle*? What is an *right angle triangle*?

A *right triangle* or *right angledtriangle* is a triangle that has a *right angle*. The right angle is formed by a vertical line and a horizontal line. Remember that these are perpendicular lines. Perpendicular lines always form right angles.

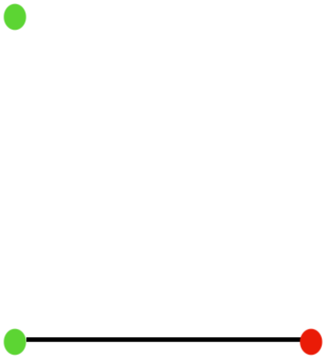
The first step in drawing an *right angle triangle* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

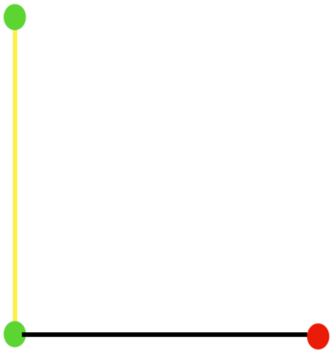
The second step is to draw a vertical line in yellow whose starting point is above the starting point of the horizontal base line. The vertical line can be any length. Do you remember what type of angle the vertical line and horizontal line form? These two lines form a right angle. The two lines that form a right angle are called perpendicular lines.

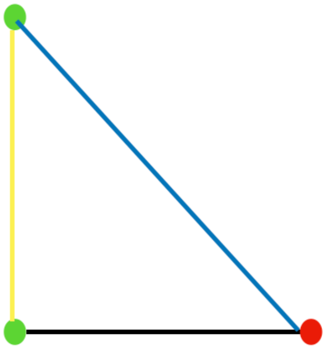
The next step is to connect the top of the vertical line to the end point of the horizontal base line with an oblique line that is blue.

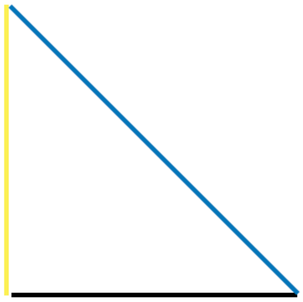
This is a *right triangle* or *right angle triangle* because of the right angle formed by the perpendicular lines.

Drawing Right Angled Triangle









Drawing Triangles: Acute and Obtuse Triangles

We will now learn how to draw an *acute triangle*. What does an *acute triangle* look like? How does an *acute triangle* look different than an *right angled triangle*?What is an *acute triangle*?An *acute triangle* is a triangle that has only acute angles. Acute angles are smaller than right angles.

The first step in drawing an *acute triangle* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

The second step is to find the starting point. Then above the starting point and to the right place a green point. Next connect the two green points to with an orange oblique line. We can see that the angle that is formed is an *acute angle*. It is smaller than a right angle.

Then with another oblique line in blue we need to connect the green point that is above and to the right of the starting point of the horizontal line to the red point on the horizontal line. This oblique line and the horizontal line also form an *acute angle*.

If we look at all three angles of the triangle we just drew we can see that all of the angles are *acute angles*. That is why it is called an *acute triangle*.

Drawing an Obtuse Triangle

We will now learn how to draw an *obtuse triangle*. What does an *obtuse triangle* look like? How does an *obtuse triangle* look different than an *acute triangle*? What is an *obtuse triangle*?

An *obtuse triangle* is a triangle that has an *obtuse angle*.

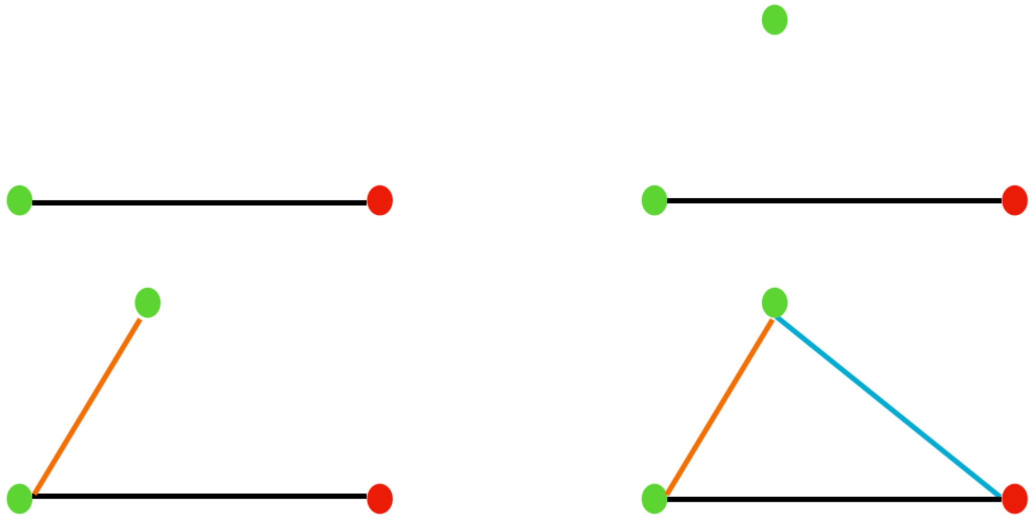
The first step in drawing an *obtuse triangle* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

The second step is to find the starting point. Then above the starting point and to the left place a green point. Next connect the two green points to with an orange oblique line. The angle that is formed by the oblique line and the horizontal line in an *obtuse angle*, meaning it is *larger* than a right angle.

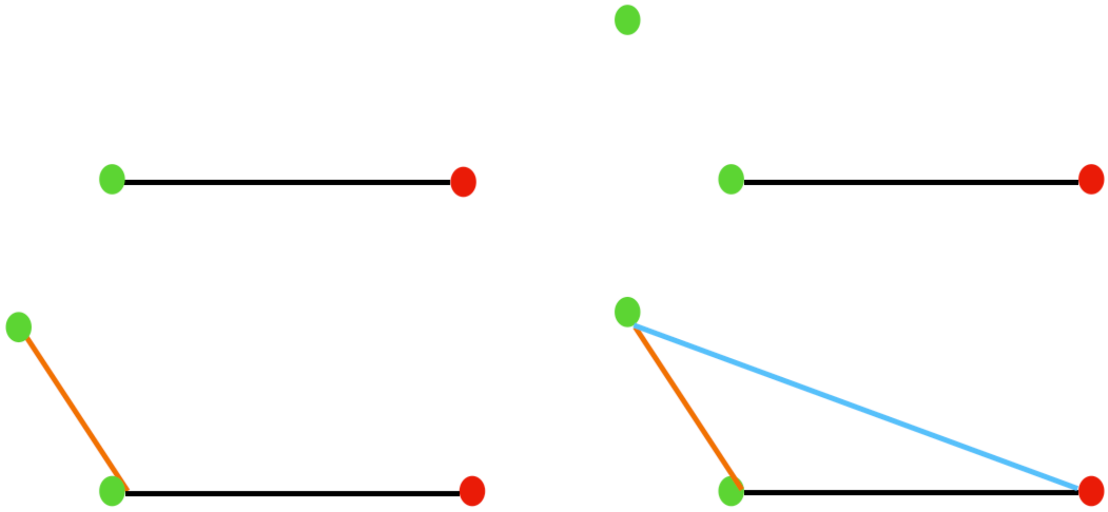
Then with another oblique line in blue we need to connect the green point that is above the horizontal line to the red point on the horizontal line. The two angles formed by this blue oblique line are acute angles.

An *obtuse triangle* has one *obtuse angle* and two acute angles. It is called an *obtuse triangle* because of its *obtuse angle*.

Drawing an Acute Triangle



Drawing an Obtuse Triangle



Review

What is a rectilinear figure?

What is a triangle?

How many sides does a triangle have?

How do we draw an equilateral triangle? What does it look like?

How do we draw an isosceles triangle? What does it look like?

How do we draw an obtuse triangle? What does it look like?

Why do these three triangles look different from one another?

How do we draw a right triangle? Why is it called a right triangle?

How do we draw an acute triangle? Why is it called an acute triangle?

How do we draw an obtuse triangle? Why is it called an obtuse triangle?

How many different types of triangles are there?

Quadrilaterals

Quadrilaterals

The next rectilinear figures we will learn about are *quadrilaterals*. What does a *quadrilateral* look like? How does a *quadrilateral* look different than a circle and a triangle? What is a *quadrilateral*?

The word *quadrilateral* literally means a figure formed with four sides. It comes from the Latin words "*quadri*" which means four and "*latus*" which means side. It is different than a triangle because it has one more side and one more angle. If you play sports, many fields are in the shape of a *quadrilateral*. For example, a football field is in the form of a *quadrilateral*, a basketball court is in the field of a *quadrilateral*, a soccer field is a *quadrilateral*, and also a tennis court is a *quadrilateral*.

There are different types of *quadrilaterals.*

The first four sided figure, or *quadrilateral* that we will learn about is the the *square*. A *square* is a figure that has all four sides equal to each other, and all four of its angles are right angles. The vertical sides and the horizontal sides are parallel to each other.

A *rhombus* is a *quadrilateral* in which all four sides are equal, but its angles are not at right angles. It is different from a square because it does not have any right angles. It looks similar to a square because all of the sides of a *rhombus* are the same distance and its opposite sides are parallel to one another.

The third *quadrilateral* we will learn about is called a *rectangle*. A *rectangle* is a figure that has four sides. In a *rectangle* the vertical sides are the same distance, and the horizontal sides are the same distance. However, the vertical sides and the horizontal sides are not equal to each other. The vertical sides and horizontal sides are parallel to one another. The *rectangle* is different than a square because the vertical sides and horizontal sides are not equal to each other. It is like a square because its composed of four sides and it has four right angles.

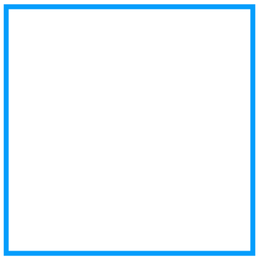
A *rhomboid* is a *quadrilateral* which has its opposite sides equal to one another, but are different lengths. A *rhomboid* does not have any right angles. Its opposite sides are parallel to each other. A *rhomboid* is different than a rectangle because it does not have any right angles. It is similar to a rectangle because the two opposite sides are equal to one other and parallel to one another.

All other types of *quadrilaterals* are called trapezoids.

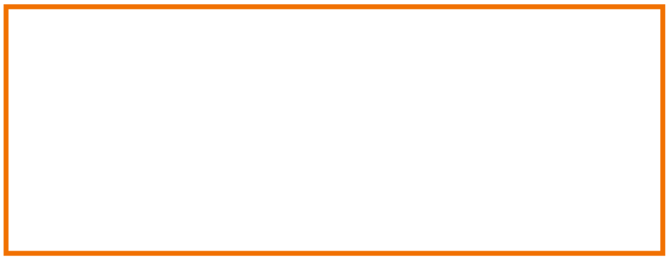
If we look at the different *quadrilaterals* on the next page can you describe the sides of each of them? Can we notice what shapes look similar and different? Can we describe what looks similar and what looks different in each of the shapes?

Quadrilaterals

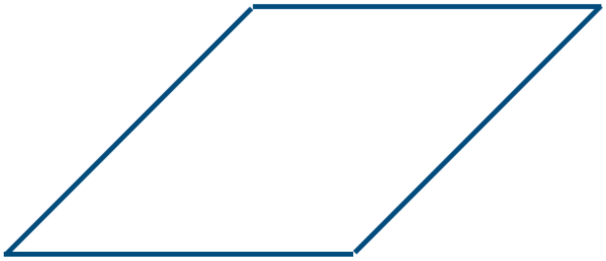
Square



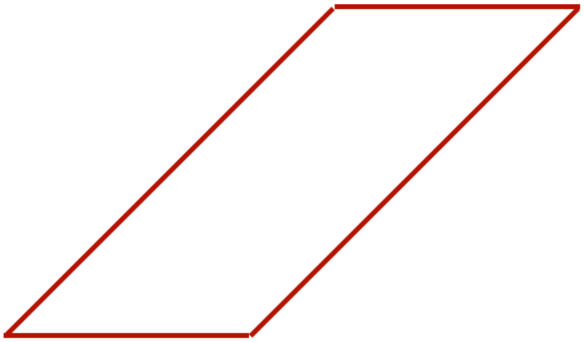
Rectangle



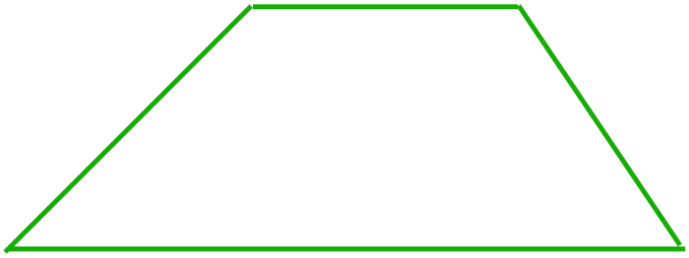
Rhombus



Rhomboid



Trapezoid



Drawing Quadrilaterals: The Square

We will now learn how to draw our first quadrilateral, the *square*. What does a *square* look like? What is a *square*?

A *square* is a quadrilateral whose sides are equal, and that has four right angles.

The word *square* comes from the Latin verb "*exquadrare*" which means to square. The prefix -*ex* in Latin means out of and the root verb -*quadrare* means to make square, set in order, complete.

The first step in drawing a *square* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

Next starting with the green point of the base draw a vertical line in orange that is the same length as the base. If we have a compass we can use the compass to determine the measurement of the base, and then use the same measurement to find the length of the vertical line. Remember when a vertical line stands on a horizontal line the lines are perpendicular and they form a right angle.

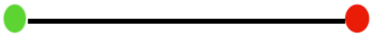
The third step is draw another vertical line in orange from the red point of the base. It also needs to be the same length as the base.

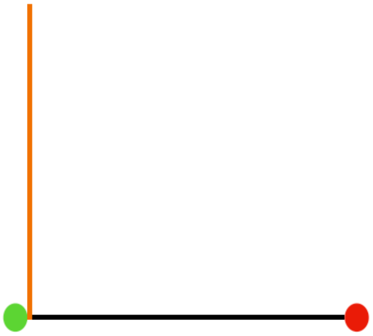
Finally connect the top points of the vertical line in black to form a *square*.

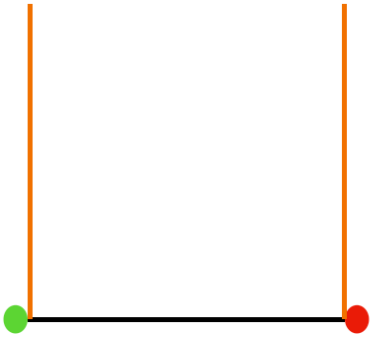
We can see that a *square* is a geometric figure whose four sides are equal and all of its angles are right angles.

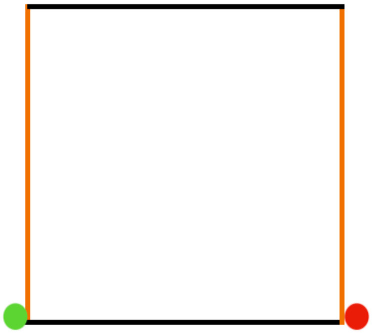
Also notice that the base and the top horizontal line are parallel to each other. The two vertical sides that are in orange are also parallel to each other.

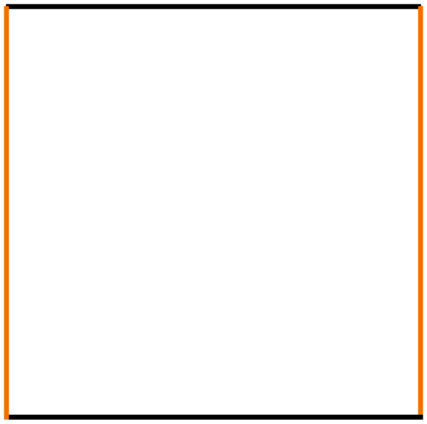
Drawing Squares











Drawing Quadrilaterals: The Rhombus

The next quadrilateral figure that we will learn how to draw is the *rhombus*. What does a *rhombus* look like? How does a *rhombus* look different than a square?What is a *rhombus*?

A *rhombus* is a quadrilateral whose fours sides are equal in distance, but whose angles are not right angles.

The word *rhombus* comes from the Greek word "*ῥόμβος*", which means something that spins, or turns around.

The first step in drawing a *rhombus* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

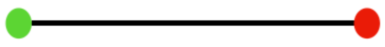
The second step is to find the starting point of the horizontal line and to place a point in blue above it and to the right. Then connect the points with an orange oblique line.

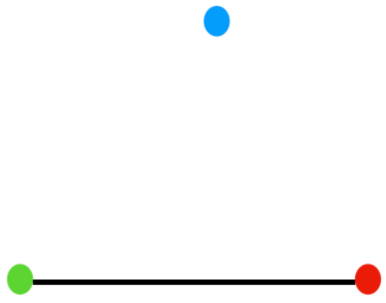
The third step is find the end point of the horizontal line and to place another point in pink above it and to the right. The space between the red point and the pink point should be the same as the space between the green point and the blue point. Then connect the red point and the pink point with an orange oblique line.

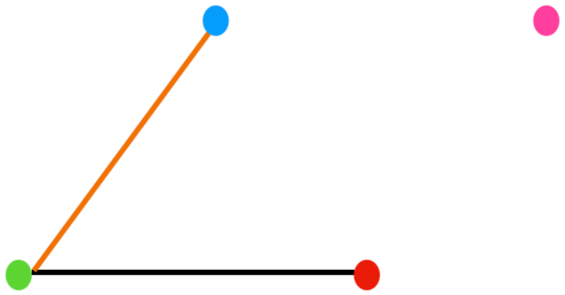
We can see that the *rhombus* looks different than the square because it does not have any right angles. It looks similar to the square because all of its sides are an equal length.

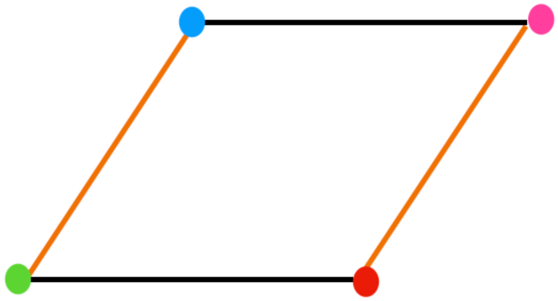
Also notice that the horizontal base and the horizontal top side in black are parallel, and that the two oblique sides in orange are also parallel.

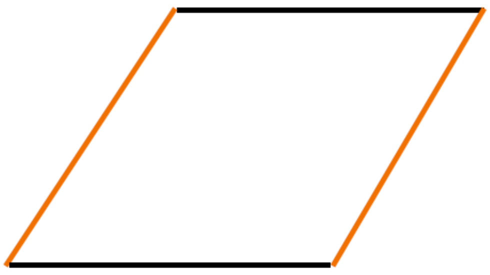
Drawing the Rhombus











Drawing Quadrilaterals: Rectangles

The next quadrilateral figure that we will learn how to draw is the *rectangle*. What does a *rectangle* look like? How does a *rectangle* look different than a square and a rhombus? What is a *rectangle*?

A *rectangle* is a quadrilateral whose opposite sides are equal to each other and are parallel. The horizontal sides and the vertical sides are not equal to each other. A *rectangle* also has four right angles like a square.

The word *rectangle* has its origin in Latin. The word "*rectus*" means right or upright.

The first step in drawing a *rectangle* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

The second step is to draw a vertical line from the starting point of the base. The vertical line should be shorter than the base. These two lines are perpendicular and form a right angle.

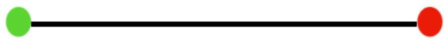
Next draw another vertical line from the end point of the base that is the same length as the first vertical line that you drew. The two line are perpendicular and form a right angle.

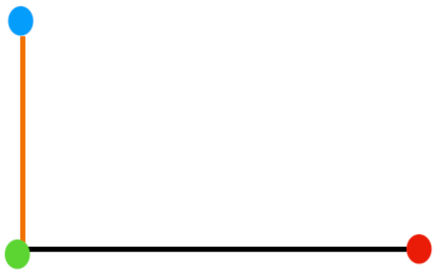
The fourth step consists in connecting the upper points of the two vertical lines to form a horizontal line.

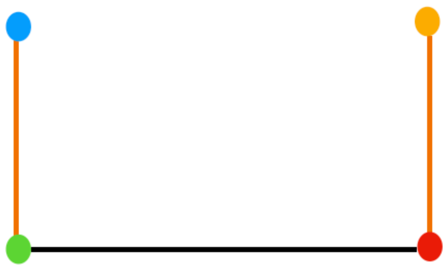
We can see that a *rectangle* is different than a square because the horizontal sides and the vertical sides are unequal, they have different lengths. A *rectangle* is similar to a square because it has four right angles.

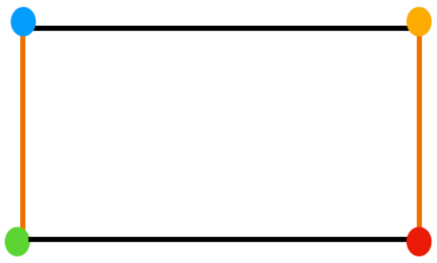
Also notice that the horizontal base is parallel to the top horizontal line, and that the two vertical sides in orange are also parallel to each other.

Drawing the Rectangle









Drawing Quadrilaterals: Rhomboids

The next quadrilateral figure that we will learn how to draw is the *rhomboid*. What does a *rhomboid* look like? How does it look different than a rectangle? What is a *rhomboid*?

A *rhomboid* is a quadrilateral whose opposite sides are parallel and are equal to each other. It is similar to a rectangle because the pair of opposite are not equal to each other. A *rhomboid* does not have any right angles.

The first step in drawing a *rhomboid* is to establish its base. The base is the horizontal line on which the figure rests. Draw a horizontal line that has a green point to indicate where it starts and a red point to indicate where it ends.

The second step is to find the starting point of the horizontal line. Then above the green point and to the left place a blue point. Now connect them to form an orange oblique line. The length of the oblique line should be shorter than the base.

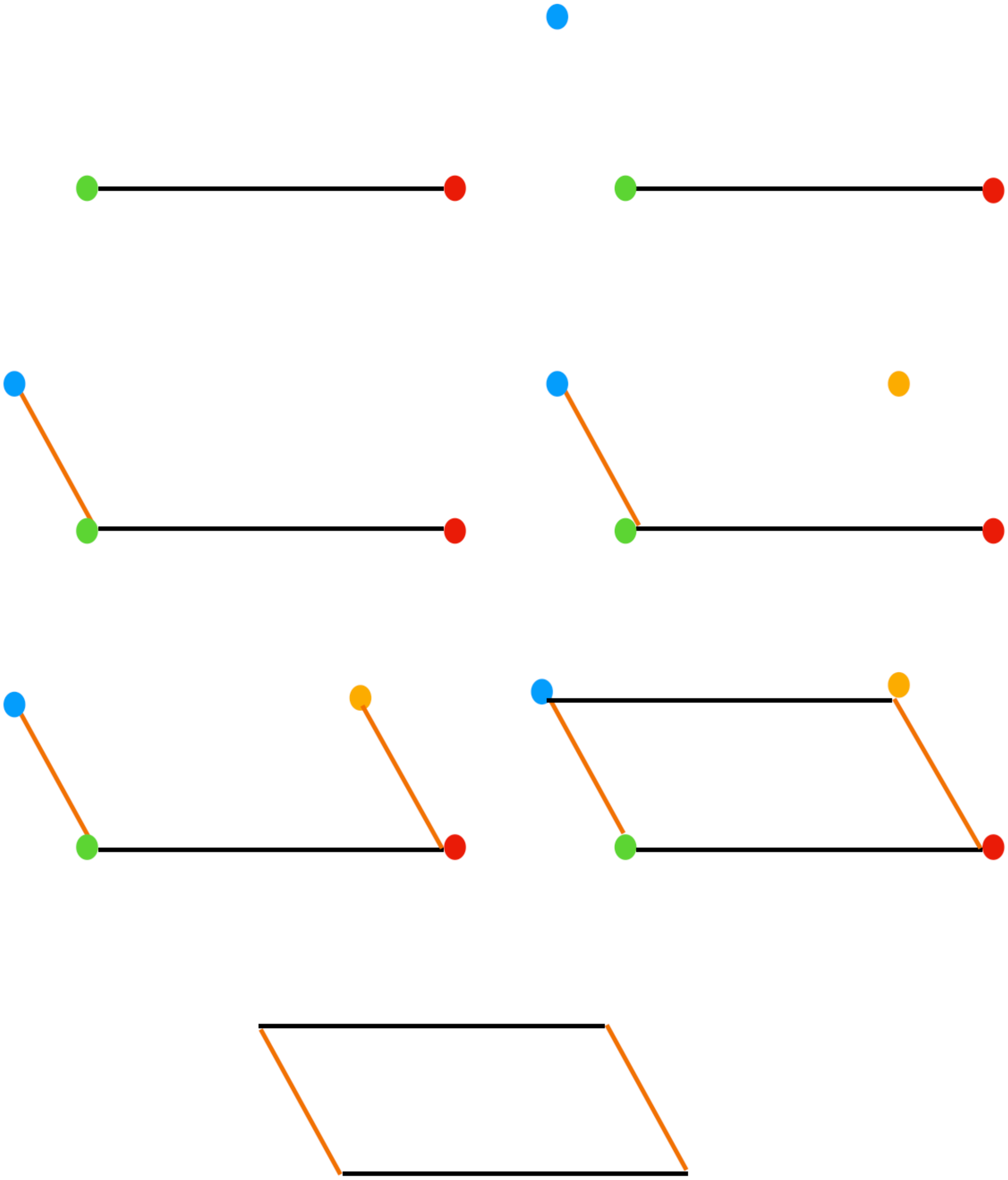
Next find the end point of the horizontal line. Then above the red point and to its left place a yellow orange point. The vertical distance above the red point and the horizontal distance to the left of the red point should be the same distance as the blue point is above and to the left of the green point. Then connect the red point and the yellow orange point to form an oblique line.

The fourth step consists in connecting the blue point to the yellow orange point with a horizontal line.

We can see that a *rhomboid* is different than a rectangle because it does not have any right angles. It is similar to a rectangle because its opposites sides equal to each other.

Also notice that the horizontal base is parallel to the top side, and the the two oblique lines in orange are also parallel.

Drawing Rhomboids



Finding the Center of Quadrilaterals

We will now learn how to find the *center point* on quadrilaterals.

First of all we need to draw a square.

After having drawn the square find the upper left corner and place a green point. Next find the bottom right corner and place a red point on the corner. Then draw a *diagonal line* from the green point point to the red point. A *diagonal* is an oblique line that runs from opposite corners on a quadrilateral.

Next place a yellow point on the upper right corner. Then place a blue point of the lower left corner. Now with a *diagonal line* connect the yellow point to the blue point.

The point where the two diagonal lines cross is the *center point* of the square. The *center point* is in the color purple.

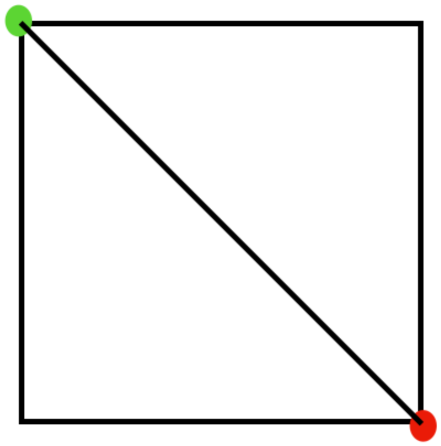
This time draw rectangle whose horizontal parallel lines are a longer distance than the vertical parallel lines.

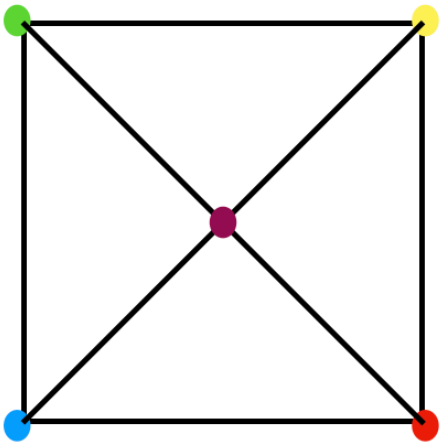
After having drawn the rectangle find the upper left corner and place a green point. Next find the bottom right corner and place a red point on the corner. Then draw a *diagonal line* from the green point point to the red point.

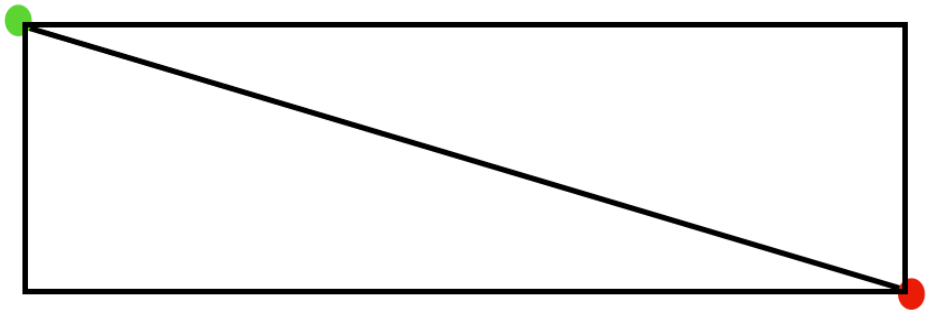
Next place a yellow point on the upper right corner. Then place a blue point of the lower left corner. Now with a *diagonal line* connect the yellow point to the blue point.

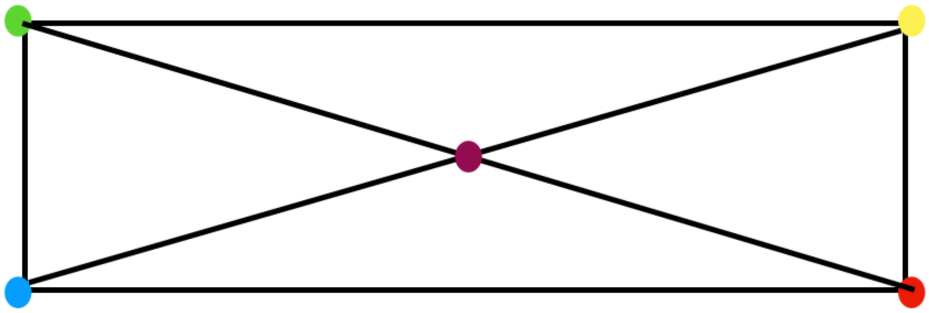
There is a purple point on the rectangle where the two diagonal lines intersect. This is the *center point* of the rectangle.

Finding the Centers of Quadrilaterals









Review

What is a rectilinear figure? What kind of lines are used in a rectilinear figures?

How do we draw a square? How do we describe what its sides look like, and what kind of angles does it have?

How do we draw a rhombus? How do we describe what its sides look like, and what kind of angles does it have?

How are a square and a rhombus different? How are they alike?

How do we draw a rectangle? How do we describe what its sides look like, and what kind of angles does it have?

How do we draw a rhomboid? How do we describe what its sides look like, and what kind of angles does it have?

How are a rectangle and a rhomboid different? How are they alike?

Geometric Design

Geometric Design: Drawing a Rosette

In this lesson we will use what we have learned about points, lines, and shapes to make a design called a *rosette*. The word *rosette* literally means a small rose.

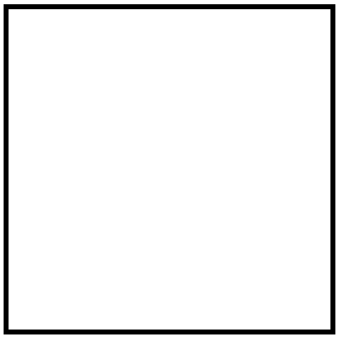
To do this we first need to draw a square. After drawing the square we need to lightly draw two diagonal lines so that we can find the center of the square. Once we have found the center of the square we need to draw a vertical line and a horizontal line that pass through the center point.

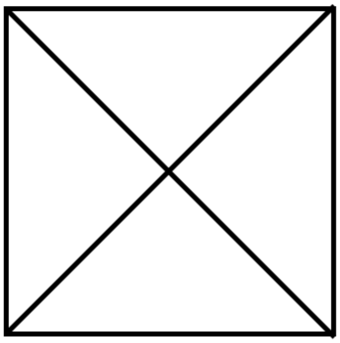
Now beginning at the upper left corner of the square we can draw a curved line in red that runs *above* the diagonal and ends at the center point of the square. Then we can draw another curved line in red that runs *below* the same diagonal line that has the same starting point and end point. This is the first leaf of the *rosette.*

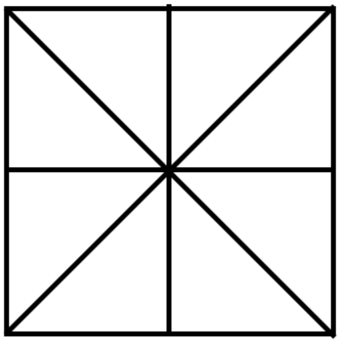
In order to complete the *rosette* we need follow the same steps on the remaining three sides of the square.

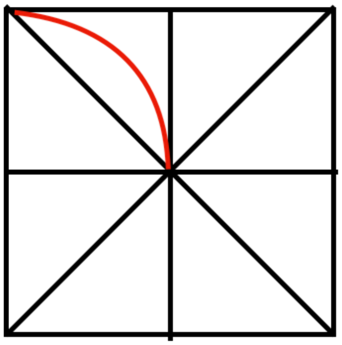
Once we have completed drawing the remaining curved lines we can erase the base and sides of the square along with the diagonals so that they only thing we see is the *rosette*.

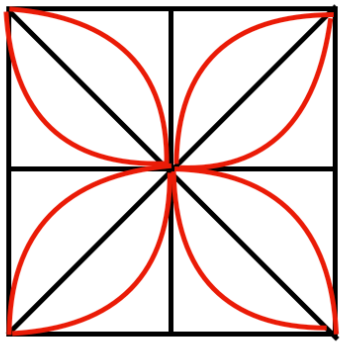
Drawing a Rosette

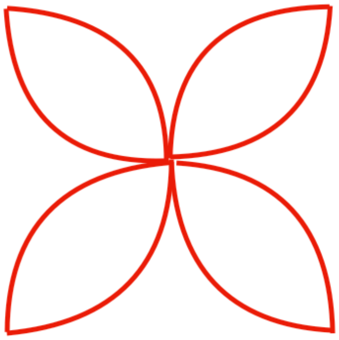












Three Dimensional Geometric Figures

Spheres, Cones, and Cylinders

Three Dimensional Geometric Figures

Earlier we learned about different geometrical figures. We learned about the circle, ellipses, triangles, and quadrilaterals. Now we will learn how to use those figures as the starting shapes to draw three dimensional figures.

What does it mean to make something look three dimensional? It means that we add a curved line or a straight line to a geometrical figure to give it the illusion of three dimensional space.

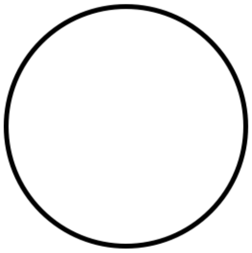
On the next page there is a circle. Beside the circle there is a sphere. The sphere has the circumference of the circle, but it also has a curved line that gives it the illusion of three dimensions. It looks solid. In geometry this is called a geometric solid.

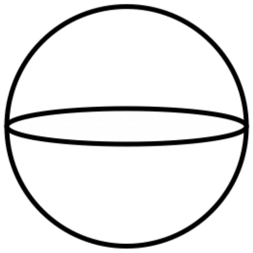
We can also see a triangle on the next page. Next to it there is a cone. When we look at the triangle we can see that the base is a horizontal line. When we look at the cone we can see that the base has become a curved line. The curved line makes the triangle look like it is three dimensional. If we could see the through the cone we would see that the curved line is really an ellipse. Like a sphere a cone is a geometric solid.

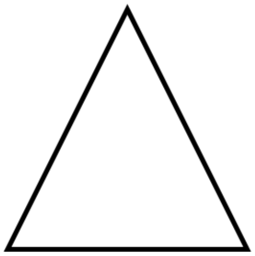
On the next page we also see a rectangle. Beside the rectangle we can see a cylinder. If we look closely we can see that the two horizontal lines of the rectangle have become curved lines. The curved line turns the rectangle into a cylinder. The curved lines make the cylinder look like it is in three dimensions. If we could see the through the rectangle we would see that the curved line is really an ellipse. A cylinder is also a geometric solid.

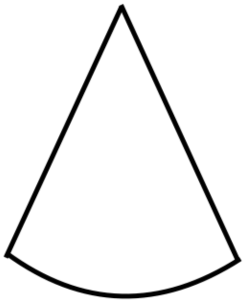
How do the two dimensional shapes look different from the three dimensional shapes? Which ones looks more realistic?

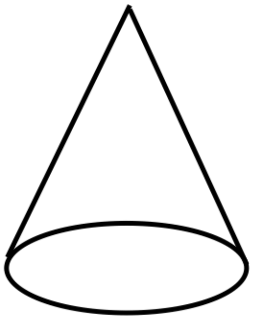
Three Dimensional Figures

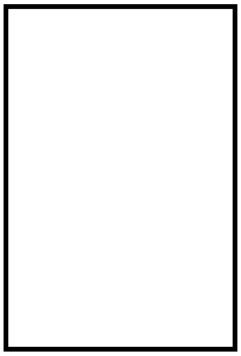


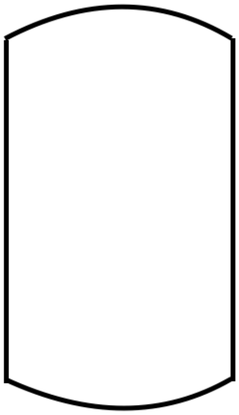


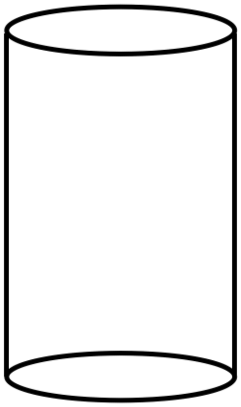












Spheres

Earlier we learned about a circle. We learned that a circle is a continuous curved line. Now we will learn about spheres. What does a sphere look like? What is a sphere?

A *sphere* is a round solid geometric figure.

The word sphere comes from the Greek word *σφαίϱα* (sfaíra), which means a globe, ball, playing ball, or terrestrial globe. A baseball, a volleyball, a tennis ball, and a basketball are all *spherical*, that means they are almost perfect *spheres.*

To draw a *sphere* we need to first of all draw a circle. Remember to draw a circle we begin with the center point and draw a line that will end at the circumference. This is the radius. Once we have drawn the radius we can then draw the circumference. Once we have drawn the circumference we need to divide the circle into quadrants. We can do this by drawing a vertical line that runs through the center of the circle and intersects the circumference on both sides. We also need to draw a horizontal line that runs through the center of the circle and intersects the circumference on both sides. These are the vertical diameter and the horizontal diameter.

Next we need to draw an ellipse. In this case the horizontal diameter will be the major axis of the ellipse. The ellipse will move towards us and go under the center point and then move toward the other point of the horizontal diameter. It will then go above the center point and connect at the most left hand point of the horizontal diameter.

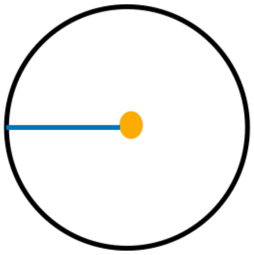
Then we need to draw an ellipse whose major axis will be the vertical diameter. The ellipse will begin at the top of the vertical diameter and will move to the left of the center point and then move toward the bottom point of the major axis. It will then go to the right of the center point and connect at the top of the vertical axis.

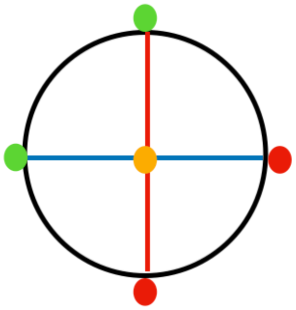
The *sphere* has a horizontal ellipse and a vertical ellipse that show that it is three dimensional or solid.

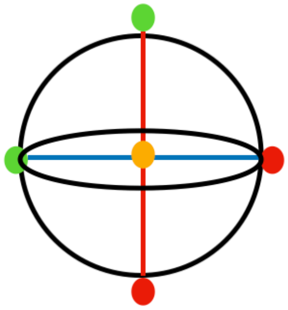
What are the characteristics of a sphere?

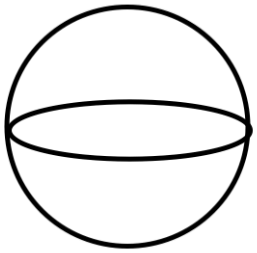
A *sphere* is a geometric solid that is formed from a circle and with ellipses. It is a curvilinear figure.

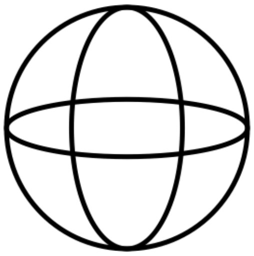
The Sphere











The Cone

The next three dimensional figure we will learn about is the *cone*. What does a *cone* look like? What is a *cone*?

A *cone* is a geometric solid that has an elliptical base and two oblique lines that meet at the apex. The apex is the uppermost point of the cone. The two oblique lines that intersect at the apex form an acute angle.

To learn how to draw a cone we need to draw a triangle. Remember to draw a triangle we first need to draw the base. Then after we have drawn the base we need to find the middle point of the horizontal base and draw a vertical line whose starting point will be above the middle point of the base. The top point of the vertical line is the apex of the triangle. From the top point of the vertical line we need to draw two oblique lines. One of the oblique lines will run from the top point of the vertical line to the starting point of the horizontal base. The other oblique point will run from the top point of the vertical line to the end point of the horizontal base.

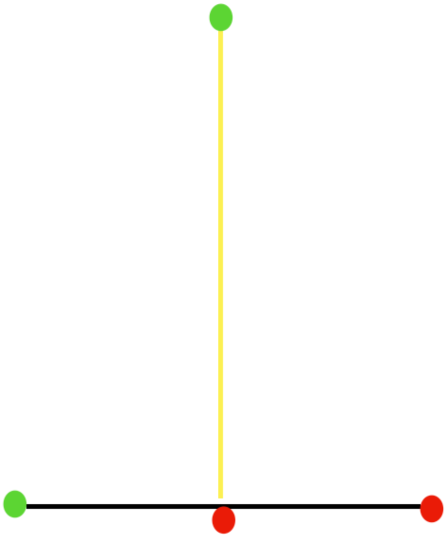
Next beginning at one of the points on the horizontal base we will draw an ellipse. The side of the ellipse closest to us will be under the base and the side of the ellipse farthest from us will be above the base. The horizontal base will become the major axis of the ellipse.

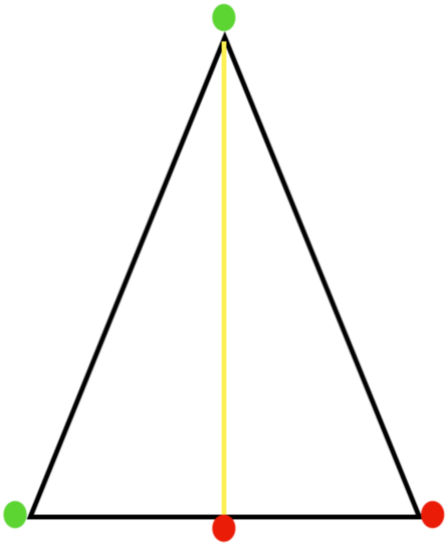
Now we can erase the horizontal base and the vertical line that we drew. We can see that we have drawn a *cone*.

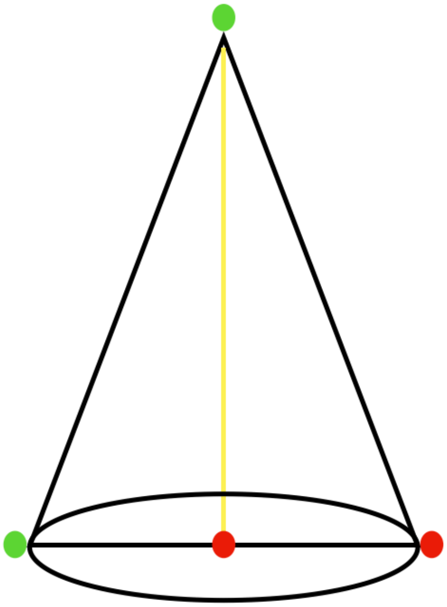
What are the characteristics of a *cone*? What lines did we use to draw a *cone*?

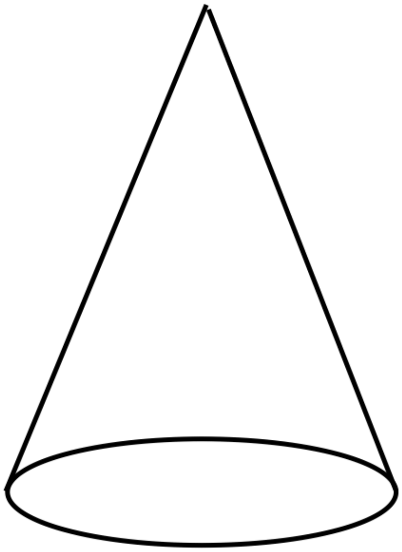
A *cone* is based on the triangle. A *cone* has three lines like a triangle. It is different than a triangle though because its base is not a straight line but a curved line. The curved line is what turns the triangle into a cone.

The Cone









The Cylinder

The next three dimensional figure we will learn about is the *cylinder*. What does a *cylinder* look like? What is a *cylinder*?

A *cylinder* is a solid geometric figure with straight parallel sides and an elliptical base and an elliptical top.

To learn how to draw a cylinder we first need to draw a rectangle. After we have drawn the rectangle we need to find its center point. Remember to find the center point of a rectangle we need to draw diagonal lines that run to opposite corners. Once we have found the center point of the rectangle we need to draw a vertical line that intersects with the upper horizontal line, and the base of the rectangle. In the example on the next page the vertical line is in yellow.

Next beginning at one of the points on the horizontal base we will draw an ellipse. The side of the ellipse closest to us will be below the horizontal base, the major axis, and the side of the ellipse farthest from us will be above the major axis.

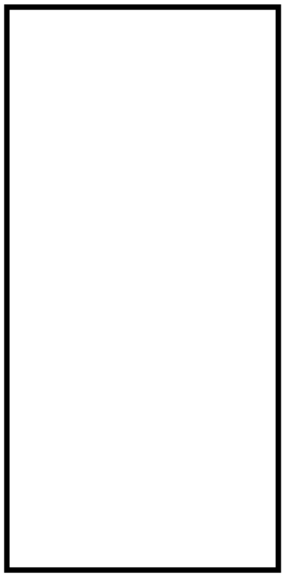
Now we will draw another ellipse at the top side of the rectangle. This time the side of the ellipse closest to us will be above the major axis and the side farthest from us will be under the major axis.

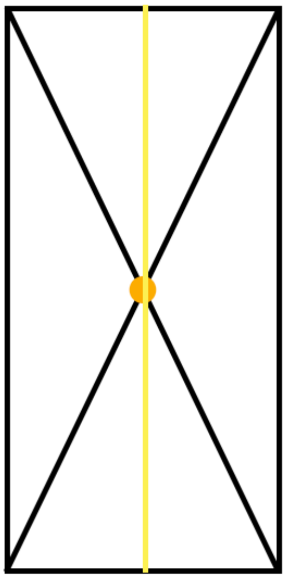
Now we can erase the rectangle and the vertical line we used as guide line and we can see that we have drawn a *cylinder*.

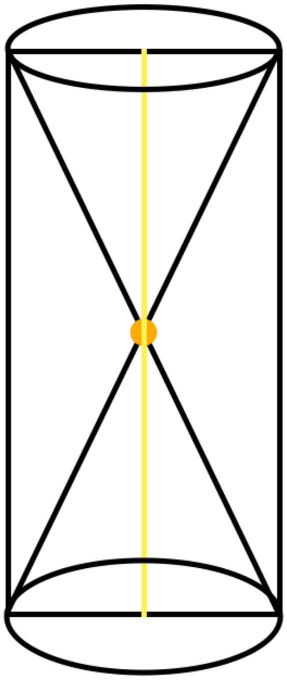
What are the characteristics of a *cylinder*? What lines did we use to draw a *cylinder*?

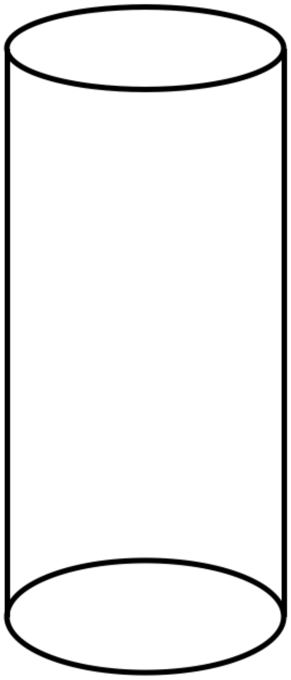
A *cylinder* is based on a rectangle. A *cylinder* has two parallel sides and an elliptical top and an elliptical base. A *cylinder* is drawn using two straight parallel lines and two curved lines.

The Cylinder









Conclusion

We have now come to the end our book on geometry. We have learned how everything we do on paper starts with points and lines. Whether we are writing or drawing we are always using points and lines. The way that we combine them allows us to write letters or to make different shapes.

In the next book, *Art with Socrates Part II*, we will use what we have learned about geometry to help us to learn to draw. Drawing, like geometry is also about making shapes. The shapes we make in drawing are somewhat different than the shapes in geometry, but geometry is the first step to learn to draw things from real life. That is why we spent so much time learning geometry, so that when we begin to draw it will be easy and fun.